Essays in International Economics and Labor Economics

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Dedication

To Amália, Ivan, João, and Mário.

Abstract

The three chapters of this dissertation investigate major puzzles in international economics and labor economics. The first chapter investigates the macroeconomic effects of primary commodities trade flows across countries with different export composition. The second chapter studies labor flows of workers with similar skill-level and across countries with similar income. Lastly, the third chapter evaluates the macroeconomic effects of a health policy in the United States.

Chapter 1 analyzes how the production and price volatility of primary commodities account for the co-movement between real GDP and terms of trade. Primary commodity exporter countries face large terms of trade fluctuations, largely driven by primary commodity price shocks and amplified by the relative importance of primary commodities in the countries' exports. In this chapter, I document that an increase in the price of a primary commodity is usually followed by a decrease in terms of trade, defined as the relative price of imports over exports, and an increase in real GDP in these countries. Meanwhile, countries that do not export primary commodities enjoy more stable terms of trade, and their real GDP is positively correlated with terms of trade. Although the literature on primary commodity exporters has focused on developing countries, I show that this relation is independent of a country's income level. Since standard models are unable to generate real aggregate fluctuations from price shocks if real GDP is correctly measured, this paper identifies a puzzle. I propose a class of mechanisms that is capable of explaining the heterogeneous impact of terms of trade fluctuations across countries. I show that a possible resolution is to incorporate the presence of idle resources and a production cost externality in the primary commodity producing sector in order to connect terms of trade fluctuations to real GDP fluctuations. When subjected to a primary commodity price shock, the model successfully accounts for the behavior of terms of trade and its relation to real GDP for different export compositions.

Chapter 2, joint work with Maria Jose Rodriguez Garcia and Rocio Madera, revisits empirical evidence on migration within the European Union-15, disaggregated by occupation. We find that workers move to countries where their type is relatively more abundant among natives. This is at odds with traditional models of migration. We develop a model with external economies of scale that generates an agglomeration force in high-educated labor. Our main result is that a country that is relatively abundant in highly educated labor force

will attract foreign labor of the same type. We argue this type of model is more suitable to analyze migration flows between countries of similar income level.

Finally, Chapter 3, joint with Juan Carlos Conesa, Parisa Kamali, Timothy Kehoe, Vegard Nygard, Gajendran Raveendranathan, and Akshar Saxena, develops an overlapping generations model to study the macroeconomic effects of an unexpected elimination of Medicare. We find that a large share of the elderly respond by substituting Medicaid for Medicare. Consequently, the government saves only 46 cents for every dollar cut in Medicare spending. We argue that a comparison of steady states is insufficient to evaluate the welfare effects of the reform. In particular, we find lower ex-ante welfare gains from eliminating Medicare when we account for the costs of transition. Lastly, we find that a majority of the current population benefits from the reform but that aggregate welfare, measured as the dollar value of the sum of wealth equivalent variations, is higher with Medicare.

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Chapter 1

From Primary Commodities to Output Fluctuations

1.1 Introduction

An increase in the international relative price of a primary commodity oftentimes produces, in a country that exports such a primary commodity, an increase in exports, a decrease in terms of trade (the relative price of imports to exports), and an increase in real GDP. In a context of intense international trade, sudden changes in primary commodity prices can provoke huge economic turmoil. Perhaps the most famous case still remains the large oil price increases in the 1970s and the sharp economic fluctuations that followed. Nonetheless, there are plenty of more recent examples that illustrate the heavy price volatility prevailing in the primary commodity markets. Synchronous to the increasing demand in China and other emergent economies, the 2000s commodities boom contributed to boost real GDP of many exporting countries. And, more recently, the 2010s commodities price collapse in the aftermath of the Great Recession has been causing a slowdown in those economies that not long ago were booming.

In this paper, I define primary commodities as goods directly extracted from natural resources that have been minimally processed. According to this definition and the importance of primary commodities in a country's export composition, I classify 46 countries into two categories: (1) primary commodity exporter (henceforth, PCX) countries or (2) non-PCX countries. I then document consistent differences across these two groups of countries with respect to primary commodity prices and macroeconomic fundamentals. In particular, I show that a large part of the variability of the terms of trade in PCX countries is associated with extreme movements in the price of the most exported primary commodity. In addition, PCX countries have a negative correlation between terms of trade fluctuations and real GDP fluctuations. Meanwhile, non-PCX countries have that correlation being positive and larger the lower the participation of primary commodities in exports. Finally, I document that both developing and developed PCX countries share these traits, therefore weakening the hypothesis that the income level of a country is essential on explaining how well it accommodates a primary commodity shock.

Given these data findings, this paper identifies the following puzzle. The theory tells us that, from the perspective of a PCX country, the rising of its primary commodity's price can be interpreted as the rest of the world attributing more value to its production and endowments, which means that the rest of the world is willing to offer more goods in exchange for the same amount of primary commodity. This unambiguously translates into larger consumption and welfare in the PCX economy. However, standard models predict that if the amount of goods the PCX is able to produce has not changed, then output at base-year prices should not see any change either (Kehoe and Ruhl, 2008). Since this is not what the data reveal, one concludes that the theory lacks a transmission mechanism from relative prices to real output.

I then propose a solution for that puzzle by identifying a class of mechanisms that fit into the standard model and that are capable of generating the observed real GDP fluctuations when primary commodity prices or the demand for primary commodities change. These mechanisms are the presence of idle resources in equilibrium and the existence of market externalities. They have in common the ability to break the envelope theorem, which, combined with chain-weighted price indexing, is responsible for cancelling out any price effect in standard models. I provide an example of how each mechanism works separately and then I explore a model with a combination of these features by incorporating two characteristics of the primary commodity sector that stand out: i) different input productivities and ii) large fixed costs for establishing an infrastructure that benefits all producers.

The empirical evidence shows that, when a primary commodity price goes up, inputs specific to the primary commodity sector that used to be idle become active or the intensity of extraction sharpens.[1] As in David Ricardo's Theory of Rent, in which land is used according to a decreasing fertility schedule, primary commodity producers exploit first the most productive natural resource input and, as the returns to production increase, incorporate the marginally less productive inputs into the production process. Provided that there is a production cost (or a satiation point), there exists an equilibrium where a fraction of the input will remain idle. Furthermore, the primary sector is highly dependent on a logistic infrastructure of distribution since it is, in general, located farther from urban centers and ports. The provision of such infrastructure entails large fixed production costs, which, once incurred, benefit all other producers in the sector. I then include an externality in that sector to represent these shared structures. Specifically, I consider that there is a fixed cost for keeping the primary commodity sector active and that, the more producers in that sector, the lower the share each individual producer pays out of the total fixed cost.

To illustrate how the model works, consider the following example. Suppose that a wheat exporter country has a large endowment of land, the natural resource required to produce wheat. Assume that land is not a homogeneous input, but rather that there is a distribution of productivities across the land endowment of that country. The productivity differentials can be interpreted as geographical conditions, rain incidence, soil pH, and so on. To simplify the intuition, let each productivity characterize a producer, who takes the international price of wheat as given and decides how much to produce. Assuming a decreasing returns to scale technology, which is reasonable since, given technology constraints, there is a limit for acreage yields, each producer has an optimal size that is consistent with her land's

[1] See Sant'Anna (2015) and Kellogg (2014) for quantitative studies.

productivity. In particular, it might be optimal for some producers to remain idle instead of paying a fixed cost to produce at a low productivity. If international wheat prices go up, some producers who were formerly idle might now find it profitable to produce, which increases wheat output, moves labor from other sectors of the economy toward the wheat-producing sector, and decreases the output of these other sectors. In addition, the entry of new wheat producers reduces the fixed cost burden for each individual producer, which further enhances the chances of formerly idle producers becoming active. As a result, the market value difference between the increase in wheat production and the decrease in other sectors' production is positive, so real GDP goes up. When subjected to an increasing demand for a primary commodity, or equivalently, to a primary commodity price increase, the model can reproduce the movements of primary commodity exports, terms of trade, and real GDP of a PCX economy.

This is a relevant outcome because accounting for increases in real GDP that coincide with price movements alone is challenging. Kehoe and Ruhl (2008) show that standard models fail to generate first-order effects on real GDP when terms of trade change. They note that this result is expected for two reasons: first, because in these models, changes in relative prices do not induce reallocations across goods and sectors that involve nonproductive activities or capital going idle; and second, because the real GDP measure was constructed precisely to neutralize relative price changes.

More recently, Llosa (2012) and de Soyres (2016), seeking a theoretical framework to connect trade and business cycle synchronization, introduced a mechanism that is able to generate real GDP changes arising from terms of trade fluctuations. They do so by incorporating love for variety and monopolistic competition in intermediate good markets. However, these elements allow for real GDP to be affected by foreign shocks by breaking the link between imports and production, whereas the discrepancies I document between PCX and non-PCX are on the export side. Moreover, the patterns I document are robust across a variety of countries with a very diverse import composition.

Numerous papers have been written about primary commodity price shocks and their impact on PCX economies; see, for example, Blattman *et al.* (2007), Hausmann *et al.* (2007), Fernandez *et al.* (2015), and Deaton (1999). However, these papers limit the primary commodity exporting role to developing countries and attribute some of the dynamics of what happens in the primary commodity sector to this lower development level. Moreover, the models constructed to analyze a PCX reaction to an increasing demand for a primary commodity (or its price increase) avoid evaluating real GDP consequences and instead focus on nominal GDP, tax revenues, economic growth, or welfare.[2]

[2] See, for example, Mendoza (1997), Eicher *et al.* (2008), Gylfason and Zoega (2002), and Lopez-Martin

Nevertheless, the empirical literature has largely documented real GDP changes in PCX economies following fluctuations in their primary commodity's price in the international markets. Cavalcanti *et al.* (2015) construct a commodity terms of trade and find that its appreciation enhances real output per capita, but its volatility exerts a negative impact on economic growth. Becker and Mauro (2006) document a century of output drops and find that the most costly ones for emerging economies are associated with terms of trade shocks. Pfeifer *et al.* (2012) find that the effects of increased terms of trade uncertainty account for one-fifth of Chilean output fluctuations. My empirical findings show that developing and developed PCX share three characteristics: (i) large terms of trade volatility, (ii) large and abrupt changes in terms of trade tend to follow large and abrupt primary commodity price changes, and (iii) a negative correlation between terms of trade and real GDP. Meanwhile, developing and developed non-PCX countries display behaviors that contrast with the three listed above. Finally, my findings also establish that income is not a major determinant of those behaviors when terms of trade and primary commodity prices are taken into consideration.

This paper documents that a country's share of primary commodity exports in total exports is a decisive factor of real GDP and terms of trade volatilities and comovements, regardless of its income level. Considering the specificities of the primary commodity production sector, this paper argues that allowing for idle resources and/or an externality in such a sector is a route to reconcile theory and data. This paper is organized as follows. In the next section, I define primary commodities and PCX countries. I then present in section 1.3 the empirical patterns that stand out from the classification of countries as PCX or not. Section 1.4 presents the puzzle and explains what class of mechanisms is required in order to overcome that puzzle. Section 1.5 exhibits a model for the primary commodity sector and explains how it is able to generate the patterns observed in the data using a combination of the mechanisms identified in Section 1.4. Next, I explain my calibration strategy and discuss the quantitative results. The last section concludes.

1.2 Primary commodities

For the purpose of assessing the role of primary commodities in the economy, I adopt a definition of primary commodities inspired by Radetzki's *Handbook of Primary Commodities in the Global Economy* (2008, chap. 1, p. 7). Broadly, I define primary commodities as "the output from the primary sector, comprising agriculture (including hunting, forestry and fishing) and mining. These are the activities which supply unprocessed raw materials

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et al. (2016).

of agricultural and mineral origin, along with fuels, electricity and potable water, for use by other sectors of the economy." More specifically, 14 divisions, 24 groups, 2 subgroups, and 2 items from the SITC Rev.2 (see Table A.1) comprise my definition of primary commodities. Upon selecting these divisions and subdivisions, I also take into account the goods level of processing to ensure that only raw materials with minimum industrial transformation are considered as primary commodities.[3]

This definition covers three basic characteristics that I explore later in my model. First, the production process of primary commodities involves the transformation or extraction of a natural resource that is located in the country where the production process takes place. While this may sound obvious, a loose definition would classify steel as a primary commodity, which any country can easily produce by having access to imported iron and coal. Second, primary commodities are more often intermediate goods. And third, each commodity has a unique world price with little to no room for goods differentiation.

Another feature common to most primary commodities is large price volatility. For example, the standard deviation of all commodities and the energy price index is 35.9, whereas the standard deviation of the U.S. consumer price index (CPI) is 15.6. Table I shows that this is true for all countries in a selected subsample and that, for most of them, the standard deviation of their main exported primary commodity price is also larger than their respective CPI. Because of the large volatility of primary commodity prices, one also expects the terms of trade of a commodity exporter country to be more volatile than those of nonprimary commodity exporters. In the next section, I show that this is indeed the case, but before that a definition of primary commodity exporter is required.

I consider a country to be a primary commodity exporter (PCX) if its average share of primary commodity exports in total goods exports is larger than the average of that statistic among the 48 countries considered throughout the period 1990 to 2015, that is, if primary commodities constitute more than 22% of the exported goods. Data availability is the only restriction for the number of countries analyzed in this paper. I use quarterly data for the years 1990 to 2015 and find a total of 48 countries with a long enough series.[4] I complement this analysis with annual data for 8 countries in order to have more non-PCX developing countries for a comparison, which are shown separately.[5] I restrict the period analyzed to have roughly the same number of observations for each country because most

[3]For example, division 04 includes cereals and cereal preparations, and whereas the group with the description "wheat and meslin, unmilled" is here considered a primary commodity, the one described as "cereal, flour or starch preparations of fruits or vegetables" is considered an industrialized good.

[4]Table A.2 in the appendix lists all countries analyzed and the period for which data are available for each of them.

[5]While the quarterly data set provides us more observations, the annual one covers a larger number of countries. Table A.3 in the appendix lists these countries.

developing countries do not have much data before 1990. In spite of this restriction, the period considered features a lot of action in the primary commodity markets, notably the primary commodity price boom of the early 2000s and its subsequent bust that followed the international recession of the late 2000s.

Given the definition of primary commodities and the definition of a PCX, my sample consists of 27 non-PCX countries and 14 PCX countries.[6] The country with the largest participation of primary commodities in exports is Australia with an average of 63% of primary commodities in its exports. Japan has the lowest participation, with a little less than 1% of primary commodities in its exports. So, although my sample spans a limited number of countries, it is able to capture a diverse group of countries with respect to export composition. Table II reports the export share of primary commodities and, to get a sense of the export concentration at the commodity level, the export share accounted for by each of the top two commodity exports.

1.3 Empirical findings

In this section, I present the properties of economies with different export compositions with respect to primary commodities. I focus on three main economic indicators: (i) main exported primary commodity price, (ii) terms of trade, and (iii) real GDP. The rationale behind the analysis of these indicators is that changes in relative primary commodity prices affect production sector decisions by signaling how much more or less profitable it is to sell a good domestically or abroad or both, how much more or less costly certain inputs become, and so on. Within the interaction between these signals and decisions dwell the terms of trade. In the presence of externalities or other market failures, this interaction results in changes in real GDP. Hence, my analysis focuses on these three indicators in an effort to capture possible disruptions originating from primary commodity price volatility.

My PCX versus non-PCX classification is highly successful in identifying distinct patterns for each of these two groups of countries. The successes and failures of the model presented in section 1.5 depend on their ability to account for these patterns.

I follow the convention in Backus, Kehoe, and Kydland (1994) (hereafter BKK), according to which the definition of terms of trade is the relative price of imports to exports. In the data, it is computed as the ratio of the implicit price deflator for imports to the implicit price deflator for exports, with deflators computed as the ratios of current-price imports and exports to base-year-price imports and exports. The series of primary commodities prices, originally in U.S. dollars, are divided by the quarterly U.S. GDP deflator to arrive at a

[6] Including the annual data countries, that amounts to 31 non-PCX countries and 18 PCX countries.

constant dollar measure. All statistics refer to HP-filtered variables, and except for the net export ratio, all variables are transformed to logarithms before filtering, unless explicitly mentioned otherwise.

1.3.1 Commodity prices and terms of trade

The goal of this subsection is to measure the quantitative importance of primary commodity prices in determining terms of trade. Once I establish this relationship, I will turn in the next subsection to the quantitative importance of terms of trade in determining real GDP. I start by reporting in Table III the basic statistics of the logarithms of the relative prices studied.

As extensively documented in the literature, I find a large volatility and persistence of these two prices. The average standard deviation of the terms of trade ranges from 0.19 to 0.09, depending on the exporting status of the country group. And, as expected, the individual commodity prices are more volatile than the terms of trade, with an average standard deviation ranging from 0.56 to 0.46. PCX countries display larger terms of trade volatility and tend to specialize in the most volatile primary commodities whose prices are more volatile.

Many papers have addressed the terms of trade risks faced by developing countries and how the world prices of the primary commodities they export affect their terms of trade (for example, see Bidarkota and Crucini, 2000). Below, I show evidence that this relation goes through for all PCX countries, despite their development level. In contrast, both developing and developed non-PCX countries face lower terms of trade volatility.

Table I shows that primary commodities display more price fluctuations as compared to the selected country consumer's basket of goods prices. The larger the participation of a primary commodity in a country's exports, the more one expects its terms of trade to fluctuate. Similarly, the larger the fluctuations in the exported primary commodity prices, the larger the fluctuations in terms of trade. Figure 1.1 confirms the first hypothesis and displays no pattern other than that of export composition, featuring developed and developing countries with similar levels of primary commodity exports behaving similarly, with India being the only outlier among the 30 non-PCX countries in my sample. Figure 1.2 confirms the second hypothesis for PCX countries, showing that, in general, a large standard deviation of the price fluctuations of the main primary commodity exported entails a large standard deviation of terms of trade fluctuations.

Now that it has been established that terms of trade in PCX countries are more volatile and have a volatility increasing in the price of the main primary commodity exported, I want to analyze how the terms of trade fluctuate compared to commodity price fluctuations. Figure 1.3 plots the price for the main primary commodity exported against the terms of trade for Australia, Austria, Chile, and Turkey. Two observations can be made directly from the figure. First, large and abrupt changes in terms of trade tend to follow large and abrupt primary commodity price changes for all four countries. So, as expected, fluctuations in the price of the most exported primary commodity seem to be driving a lot of the terms of trade fluctuations. The second observation is that, again, I find opposite patterns for PCX and non-PCX countries. For the PCX countries, Australia and Chile, terms of trade and primary commodity prices are negatively correlated, whereas for the non-PCX countries, Austria and Turkey, they are positively correlated.[7] Figure 1.4 shows that this pattern holds for most of the other countries in my sample.

Given this evidence, I conclude that export concentration in primary commodities and a larger volatility of primary commodity prices are the crucial characteristics to determine terms of trade volatility.

1.3.2 Terms of trade and real GDP comovements

In this subsection, I document a novel fact relating terms of trade and real GDP where the major determinant is a country's export composition.

When a PCX's main export price goes up, there is a subsequent terms of trade deterioration, and one expects this to be a good period for this PCX's economic growth. The first part of this chain has already been documented in the previous subsection; this subsection documents the second part. I take the correlation between terms of trade and real GDP and analyze how it changes according to the share of primary commodities exported. Figure 1.5 exhibits the existence of a clear pattern dividing the two country groups. While most PCX countries benefit from a terms of trade decrease, the opposite happens for non-PCX countries. This observation is consistent with the expectation outlined in the first sentence of this paragraph; that is, a PCX's real GDP increases when its terms of trade appreciate (i.e., decrease).

This negative relationship between the correlation of terms of trade and real GDP and the share of primary commodities exported is robust for different time frames and for different

[7] Backus and Crucini (2000) document a similar relationship for net oil exporters and importers. They find that "the most dramatic shifts in the terms of trade are synchronous with changes in the relative price of oil" (Backus and Crucini, 2000, p. 190) and that Canada, a net oil exporter, has a negative correlation between oil price and terms of trade, whereas the United States, a net oil importer, has a positive one. The pattern I document here, however, holds for the main exported primary commodity, and it is surprising even for a non-PCX country that its terms of trade increase when the price of its main primary commodity increases.

measures of terms of trade and real GDP innovations.[8]

Comparing Figures 1.4 and 1.5 gives us an idea about the strength of the relationship between commodity prices, terms of trade, and real GDP when the export composition of a country is considered. Finally, the first three columns of Table IV summarize the facts discussed in this subsection and the previous subsection.

1.3.3 Commodity exports versus developing countries

The production and export of primary commodities have been historically associated with developing countries, especially those with a colonial past, when they used to supply these commodities to the colonial powers in exchange for manufactured goods. To address the natural question of whether the true pattern arises from the developing versus developed dimension, I first compare the average statistics calculated for the PCX and non-PCX countries with those for the developing and developed countries.

I consider a country to be developed if it satisfies the World Bank criterion for being a high-income country, that is, a GNI per capita of US$12,616 or more, on average, during the period 1990 to 2015. My sample has 14 PCX countries, 6 of which are developed countries and the remaining 8 developing, so there is a fair balance in this regard. With respect to non-PCX countries, my sample has 12 developing countries and 17 developed, so again both groups are fairly represented (see column 6 of Table II).

Table IV shows that the average standard deviation of terms of trade for PCX countries is twice as large as that for non-PCX countries and that, while developing countries display a larger terms of trade volatility than developed countries, their terms of trade volatility is still below that of PCX countries. The real GDP volatility is larger for PCX countries, but also larger for developing countries than for developed countries of either PCX or non-PCX group. And, finally, the negative correlation between terms of trade and real GDP seems to be mostly driven by the export composition. I interpret these findings as evidence that income and development are not the main causes of the contrasting patterns documented in the last two subsections; rather the importance of primary commodities in overall exports is of utmost importance when analyzing aggregate fluctuations and their responsiveness with respect to terms of trade fluctuations.

I also sort countries into four mutually exclusive groups with respect to being a PCX country or not and being a developed country or not. Consider the following regression in

[8] For earlier periods, the number of countries remaining in the sample is smaller, but the relationship is still robust. The alternative measure of innovations is the first difference in logs. These alternative specifications are available upon request.

which real GDP is the dependent variable, terms of trade is the independent variable, and i indexes a country:

$$gdp_{i,t} = \alpha_0 + \sum_{i=1}^{48} \sum_{j=1}^{4} \alpha_j D_{i,j} ToT_{i,t} + \varepsilon_t,$$

where $D_{i,j}$ is a dummy variable corresponding to the following mutually exclusive categories: (1) developed and non-PCX countries; (2) developed and PCX countries; (3) developing and PCX countries; and (4) developing and non-PCX countries.

Table V displays the results of this regression. These coefficients serve as an alternative measure of the average correlation between terms of trade and real GDP for each group of countries. If the main driver behind the negative correlation is indeed the export composition instead of the income level, the coefficients must be significantly negative for the PCX groups and positive for the non-PCX groups. Coefficients are statistically significant at the 10% level of significance, with the exception of the coefficient for developing non-PCX countries. For primary commodity exporters, the coefficients are -0.048 for developed countries and -0.069 for developing countries. The coefficient for developed non-PCX countries is 0.181. These results corroborate the conjecture that export composition is a better predictor of the sign of the correlation between terms of trade and real GDP than the income level of a country. In the next section, I demonstrate why standard models fail to generate this relation and then provide a new theoretical framework that can successfully account for it.

1.4 Terms of trade and output fluctuations: a puzzle

Kehoe and Ruhl (2008) show that, in a frictionless standard model, changes in terms of trade do not carry onto real GDP in an economy that imports intermediate goods and exports final goods. In this section, I show that their model can be adapted to an environment of a primary commodity exporting economy and that the same argument for the invariance of real GDP holds. In order to simplify the exposition, I will consider the simplest open economy environment presented in Kehoe and Ruhl (2008), but similar results extend to all cases considered by them.

1.4.1 The benchmark model and the puzzle

Consider an open economy where there are three tradable goods: (i) a domestic final good, (ii) a foreign final good, and (iii) an intermediate good that represents the primary commodity.[9] There is also a nontradable good that serves as an input to the production of

[9]Notice that this economy has an extra good, the foreign final good, than the economy of Kehoe and Ruhl (2008). The reason for this inclusion is that here I focus on the exporting effects side, while the original

primary commodities and will be referred to as natural resources. All markets are perfectly competitive and can be represented by a representative agent.

Following my definition of primary commodities, I assume primary commodities serve as inputs to the production of final goods and have a unique world price that is more volatile than the overall price level of the economy. Assume the production in this sector takes natural resources and labor as inputs according to the production function

$$y_{c,t} = f(\ell_{c,t}, N_t), \tag{1.1}$$

where f has constant returns to scale, is concave, and is continuously differentiable.

For the PCX economy, the output of the primary commodity sector is only partially consumed as an input in the production of domestic final goods, c_t^c, and the rest is exported.[10] Let the maximization problem of domestic final good producers be

$$\begin{aligned} \max_{c_t^c, \ell_{d,t}} \; & p_{d,t} y_{d,t} - p_{c,t} c_t^c - w_t \ell_{d,t} \\ \text{s.t.} \;\; & y_{d,t} \leq F(c_t^c, \ell_{d,t}), \end{aligned} \tag{1.2}$$

where $F(c_t^c, \ell_{d,t}) = A_{d,t}(c_t^c)^{\alpha} \ell_{d,t}^{1-\alpha}$.

Consumers have fixed endowments $\bar{L}$ of labor and $\bar{N}$ of natural resources, which they supply inelastically. They consume the following basket of goods:

$$C_t = \left(\omega c_{d,t}^{\frac{\sigma-1}{\sigma}} + (1-\omega)\, c_{f,t}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}, \tag{1.3}$$

where $c_{d,t}$ is the consumption of the domestic final good, $c_{f,t}$ is the consumption of the foreign final good, ω is a home bias parameter, and σ is the elasticity of substitution between domestic and foreign goods. As in Armington (1969), I assume that goods produced in different countries are intrinsically different goods, yet substitutable for each other to some extent. Consumers' budget constraint is

$$p_{d,t} c_{d,t} + p_{f,t} c_{f,t} \leq w_t \bar{L} + r_t \bar{N}, \tag{1.4}$$

where r_t is the rental rate households charge from primary commodity producers for the services of natural resources.

model focuses on the importing effects. Nonetheless, for trade to take place the economy being studied must import some good from the rest of the world. For simplicity, I assume it to be a final good.

[10]Depending on the parameters chosen, the economy can easily become a net importer of primary commodities, instead of a net exporter.

Lastly, the condition for balanced trade is

$$p_{d,t}\left(y_{d,t}-c_{d,t}\right)+p_{c,t}\left(y_{c,t}-c_t^c\right)=p_{f,t}c_{f,t}. \tag{1.5}$$

This specification bears a close resemblance to Kehoe and Ruhl's (2008) framework, where it is easy to demonstrate that a change in the relative price of exported inputs has no impact, up to a first order approximation, on real GDP using a simple envelope theorem argument. On the expenditure side, real GDP, is

$$RGDP_t=\underbrace{p_{c,0}c_{c,t}+p_{f,0}c_{f,t}}_{C}+\underbrace{p_{d,0}\left(y_{d,t}-c_{d,t}\right)+p_{c,0}\left(y_{c,t}-c_t^c\right)}_{X}-\underbrace{p_{f,0}c_{f,t}}_{M}, \tag{1.6}$$

where $p_{k,0}$, $k\in\{d,c,f\}$, are base-year prices. And, on the output side, real GDP is calculated as the base period value of gross output minus the base period value of intermediate inputs, that is

$$\begin{aligned}RGDP_t&=p_{d,0}y_{d,t}+p_{c,0}\left(y_{c,t}-c_t^c\right)\\&=p_{d,0}F(c_t^c,\ell_{d,t})+p_{c,0}\left(f(\ell_{c,t},\bar{N})-c_t^c\right).\end{aligned} \tag{1.7}$$

Normalizing the price of the domestic final good to 1, the derivative of real GDP with respect to the primary commodity price is:

$$\frac{\partial RGDP_t}{\partial p_{c,t}}=\left[F_m(c_t^c,\ell_{d,t})\frac{\partial c_t^c}{\partial p_{c,t}}+F(c_t^c,\ell_{d,t})\frac{\partial \ell_{d,t}}{\partial p_{c,t}}\right]+p_{c,0}\left(f'(\ell_{c,t},\bar{N})\frac{\partial \ell_{c,t}}{\partial p_{c,t}}-\frac{\partial c_t^c}{\partial p_{c,t}}\right). \tag{1.8}$$

Using the first order conditions from the producers problems and the labor and natural resources markets feasibility constraints

$$\frac{\partial RGDP_t}{\partial p_{c,t}}=\left(p_{c,t}-p_{c,0}\right)\frac{\partial c_t^c}{\partial p_{c,t}}+\left(\frac{p_{c,0}}{p_{c,t}}-1\right)w_t\frac{\partial \ell_{c,t}}{\partial p_{c,t}}, \tag{1.9}$$

and with a chain weighted construction of real GDP, we have:

$$\frac{\partial RGDP_t}{\partial p_{c,t}}\approx 0. \tag{1.10}$$

This is the same result Kehoe and Ruhl (2008) find for an open economy that imports inputs. The intuition behind the invariance of real GDP is that, when the relative price of the primary commodity rises, the country decides to export more of the primary commodity and, hence, to produce less of the domestic final good. The reallocation that takes place is such that the gains from producing more in one sector are exactly offset by the losses of producing less in the other sector. This counterbalance of forces follows from the FOCs and the envelope theorem.

1.4.2 Overcoming the Kehoe-Ruhl puzzle

An obvious solution to reconcile data and theory in this framework is to consider a model that breaks with the envelope condition, generating an extra term in Equation (1.9). Here, I discuss two mechanisms that fulfill this requirement and provide simple examples.

Idle resources

As shown by Kehoe and Ruhl (2008), if individuals value leisure, the right hand side of Equation (1.10) would not be zero. The inconvenience of considering an elastic labor supply is that, for standard utility functions, the sign of that derivative would always go against the empirical evidence, and the puzzle would persist in a worsened degree. Nonetheless, understanding the variable labor supply case provides an insight.

The crucial reason for the response of the labor supply to a change in terms of trade to pass along real GDP is that leisure is not accounted for in real GDP. According to the intratemporal first order condition of the consumers, some of the time endowment, $\bar{L}$, will be devoted for leisure activities. Since real GDP only measures the makes of productive hours, it follows that a fraction of the productive resources of that economy is not accounted for in real GDP. When the incentives for working change, for instance, as a consequence of changes in terms of trade, households adjust their labor supply subsequently changing real GDP.

There are two observations worth mentioning about this. First, notice that agents are optimally operating in the margin and, as a result, their leisure has a marginal value as well, its hour marginal value equals that of working an extra hour, and their leisure time produces something – utility. However, the utility level of agents in the economy is not considered as part of the real GDP, which bring us to the second observation. An alternative measure of output that takes the "production" of utility into consideration would bring us back to the Kehoe-Ruhl puzzle. In that case, any increase of physical output derived from an increase in the labor supply would be offset by an equal decrease in the utility level.

Provided that the measure of real GDP does not change to incorporate utility, leisure is then regarded as an idle resource. Having this in mind, the possibility of idle resources in a different input context might help us solve our conundrum. For example, consider an economy identical to the one exposed above, except for the consumers side. Assume that consumers value idle natural resources as a source of sightseeing, better environmental quality, protection to endangered species, and so on. Hence, instead of maximizing consumption alone, they maximize a utility function $u(C, N)$ according to

$$\begin{aligned} \max_{C_t, N_t} \; & u(C_t, N_t) \\ \text{s.t.} \;\; & P_t C_t \leq w_t \bar{L} + r_t N_t \\ & N_t \leq \bar{N}, \end{aligned} \tag{1.11}$$

where P_t is the consumer price index corresponding to the basket of goods C_t defined in Equation (1.3). The inclusion of natural resources as a source of utility represents a competing use for it other than the production of primary commodities. Most importantly, as discussed in the elastic labor supply case, this alternative use does not weigh into real GDP. In this case, Equations (1.7)–(1.10) become:

$$RGDP_t = p_{d,0} F(c_t^c, \ell_{d,t}) + p_{c,0} \left(f(\ell_{c,t}, N_t) - c_t^c \right), \tag{1.12}$$

$$\begin{aligned} \frac{\partial RGDP_t}{\partial p_{c,t}} &= \left[F_m(c_t^c, \ell_{d,t}) \frac{\partial c_t^c}{\partial p_{c,t}} + F(c_t^c, \ell_{d,t}) \frac{\partial \ell_{d,t}}{\partial p_{c,t}} \right] + p_{c,0} \left(f_\ell(\ell_{c,t}, N_t) \frac{\partial \ell_{c,t}}{\partial p_{c,t}} - \frac{\partial c_t^c}{\partial p_{c,t}} \right) \\ &\quad + p_{c,0} f_N(\ell_{c,t}, N_t) \frac{\partial N_t}{\partial p_{c,t}} \\ &= (p_{c,t} - p_{c,0}) \frac{\partial c_t^c}{\partial p_{c,t}} + \left(\frac{p_{c,0}}{p_{c,t}} - 1 \right) w_t \frac{\partial \ell_{c,t}}{\partial p_{c,t}} + p_{c,0} \frac{r_t}{p_{c,t}} \frac{\partial N_t}{\partial p_{c,t}} \\ &\approx r_t \frac{\partial N_t}{\partial p_{c,t}}. \end{aligned} \tag{1.13}$$

Notice that the right hand side of Equation (1.13) no longer cancels out. Therefore, depending on how idle resources is incorporated into the model, it is capable of overcoming the Kehoe-Ruhl puzzle for the case of primary commodity exports.

Nevertheless, the case of idle natural resources in the utility function is more useful as an instructive example of how a mechanism works than as a model suitable for a quantitative analysis. Apart from the difficulty concerning the identification of the functional form of u and its parameters with respect to individuals' preferences for idle natural resources, the hypothesis of natural resources in the utility function as the sole culprit for all the fluctuations observed in the data is farfetched at best. On that note, I now discuss the mechanics of a different ingredient and, in Section 1.5, I explore again the contribution of idle resources to the resolution of the puzzle under different assumptions.

Externalities

In this subsection, I allow for an externality in the primary commodity sector. Consider the benchmark model with the following modification. Assume total factor productivity in the primary commodity sector is increasing with the output of that sector, but that primary commodity producers do not internalize it. In this case, the new production function of primary commodities is

$$y_{c,t} = A(Y_{c,t})f(\ell_{c,t}, N_t), \tag{1.14}$$

where f has constant returns to scale, is concave, and is continuously differentiable and $A(\cdot)$ is a continuously differentiable function increasing in $Y_{c,t}$, the total output in the primary commodity sector. Notice that $Y_{c,t} = y_{c,t}$ because primary commodity producers are homogeneous, thus one can still think of a representative primary commodity producer.

Rewriting real GDP on the output side

$$\begin{aligned} RGDP_t =& p_{d,0}F(c_t^c, \ell_{d,t}) + p_{c,0}\left[A(Y_{c,t})f(\ell_{c,t}, N_t) - c_t^c\right] \\ & p_{d,0}F(c_t^c, \ell_{d,t}) + p_{c,0}\left[A(f(\ell_{c,t}, N_t))f(\ell_{c,t}, \bar{N}_t) - c_t^c\right], \end{aligned} \tag{1.15}$$

where I substituted for the market clearing condition for natural resources. In this case, the derivative of real GDP with respect to the primary commodity price is

$$\begin{aligned} \frac{\partial RGDP_t}{\partial p_{c,t}} =& \left[F_m(c_t^c, \ell_{d,t})\frac{\partial c_t^c}{\partial p_{c,t}} + F(c_t^c, \ell_{d,t})\frac{\partial \ell_{d,t}}{\partial p_{c,t}}\right] + p_{c,0}\left(A(Y_{c,t})f_\ell(\ell_{c,t}, \bar{N}_t)\frac{\partial \ell_{c,t}}{\partial p_{c,t}} - \frac{\partial c_t^c}{\partial p_{c,t}}\right) \\ & + p_{c,0}A'(Y_{c,t})f_\ell(\ell_{c,t}, \bar{N}_t)\frac{\partial \ell_{c,t}}{\partial p_{c,t}}f(\ell_{c,t}, \bar{N}_t) \\ =& \left(p_{c,t} - p_{c,0}\right)\frac{\partial c_t^c}{\partial p_{c,t}} + \left(\frac{p_{c,0}}{p_{c,t}} - 1\right)w_t\frac{\partial \ell_{c,t}}{\partial p_{c,t}} + p_{c,0}A'(Y_{c,t})f_\ell(\ell_{c,t}, \bar{N}_t)\frac{\partial \ell_{c,t}}{\partial p_{c,t}}f(\ell_{c,t}, \bar{N}_t) \\ \approx& p_{c,0}A'(Y_{c,t})f_\ell(\ell_{c,t}, \bar{N}_t)\frac{\partial \ell_{c,t}}{\partial p_{c,t}}f(\ell_{c,t}, \bar{N}_t). \end{aligned} \tag{1.16}$$

Again, the derivative of real GDP with respect to the primary commodity price is non-zero, that is, the right hand side of Equation (1.16) does not cancel out. Therefore, externalities are another ingredient that can be added to the benchmark model such that it overcomes the Kehoe-Ruhl puzzle for the case of primary commodity exports.

This example, although didactic, is controversial. There is no consensus on the literature on whether total factor productivity in the primary commodity sector increases or decreases when the output of that sector increases. So, once more, I expose this example more as a clear illustration on how the type of mechanism required after works than a true representation of the primary commodity sector. Next, I combine the two ingredients, idle resources and externalities, into a model for the primary commodity sector whose assumptions are more realistic.

1.5 A model for the primary commodity sector

In this section, I first develop a two-country model in which one country produces and exports primary commodities while the other imports them, and I show that these countries behave as a PCX and a non-PCX, respectively. Then, to account for primary commodity price taking behavior, I present the small open economy version of the first model, which, depending on the calibration, delivers the features of a PCX or a non-PCX as documented in the empirical analysis. The environment is the same as in Section 1.4, except for the primary commodity sector, as will be clear below. Short of the presence of a primary commodity producing sector and different parameterization, the environments of both countries are symmetric, so I describe the environment for only one country.

1.5.1 Primary commodity producers

Beyond the characteristics documented in Section 1.4, I assume that each economy is endowed with an endowment N of natural resources distributed among a measure 1 of producers with a continuum of heterogeneous productivities. This assumption entails the fact that natural resources are both unevenly distributed across countries and have different properties that interfere in the efficiency of the production process. For example, in agriculture, natural resources represent arable land, and the continuum of productivities corresponds to rain conditions, soil pH, presence of organic matter, and so on. Countries can vary along both dimensions, the quantity and productivity of natural resources. Let $\tilde{A}_j$ denote the productivity of the j^{th} primary commodity producer. For simplicity, let N be a fixed factor that cannot be transferred across producers. I then simplify the notation by combining it with the productivity, that is, $A_j = \tilde{A}_j N^{1-\gamma}$. Assume $A_j \sim U[A_{\min}, A_{\max}]$.

The technology to produce primary commodities is a decreasing returns to scale production function that takes labor as an input. That implies the existence of an optimal size for each primary commodity producer. Lastly, there is a fixed production cost in terms of labor units that is subject to an externality on the measure of active producers in this sector.

Producer j's maximization problem is

$$\begin{aligned} &\max_{\ell_j} \; p_c y_j - w\left(\ell_j + \frac{f}{\mu}\right) \\ &\text{s.t.} \;\; y_j \leq A_j f(\ell_j), \end{aligned} \tag{1.17}$$

where μ is the measure of active primary commodity producers and f has decreasing returns to scale, is concave, and is continuously differentiable. Later, I analyze the case where f is a fixed proportions production function. Notice that more active producers mean a lower fixed cost for each individual producer. This positive externality captures the existence of agglomeration cost effects in the primary commodity sector, that is, large production costs that are shared among producers. I interpret these shared production costs as the provision of nonexcludable production structures required for the production of primary commodities, for instance, roads, ports, and R&D and associated changes in inputs (seeds, livestock, pesticides), among others.

Given prices and wages, primary commodity producers will be active if profits are non-negative and idle otherwise, so there is a threshold productivity, $\bar{A}$, above which production is positive. This cutoff rule implies that it is optimal, in equilibrium, to have idle natural resources in this economy, that is, potential primary commodity producers that opt out of the market.

From $\bar{A}$, one derives the measure of active producers, μ, and obtains the total production and total profits in the primary commodity sector as follows:

$$y_c = \int_{\bar{A}}^{A_{\max}} A_j f(\ell_j)\phi(dA_j) \tag{1.18}$$

$$\pi_c = p_c y_c - w \int_{\bar{A}}^{A_{\max}} \left(\ell_j + \frac{f}{\mu}\right) \phi(dA_j), \tag{1.19}$$

where ϕ denotes the uniform distribution of A_j.

1.5.2 Equilibrium

An equilibrium for the two-country model is consumption plans $\{c_d, c_f\}$ and $\left\{c_d^\star, c_f^\star\right\}$, final good production plans $\{y_d, m, \ell_d\}$ and $\{y_f, m_f, \ell_f\}$, a primary commodity production plan $\{y_j, \ell_j\}$, a productivity threshold for the primary commodity sector, $\bar{A}$, a measure μ of active primary commodity producers, and prices $\{p_c, p_d, p_f, w, w^\star\}$ such that:

1. Given prices, consumption plans maximize (1.3) subject to the appropriate budget constraint

$$p_d c_d + p_f c_f \leq w\bar{L} + \pi_c \tag{1.20}$$

$$p_d c_d^\star + p_f c_f^\star \leq w^\star \bar{L}^\star. \tag{1.21}$$

2. Given prices, final good production plans solve (1.2).

3. Given prices, the primary commodity production plan solves (1.17).

4. Given prices, $\bar{A}$ is such that

$$p_c \bar{A} f(\ell_j) - w\left(\ell_j + \frac{f}{\mu}\right) = 0, \tag{1.22}$$

and μ is given by

$$\mu = \frac{A_{\max} - \bar{A}}{A_{\max} - A_{\min}}. \tag{1.23}$$

5. Final goods markets clear:

$$c_d + c_d^\star = y_d = F(m, \ell_d) \tag{1.24}$$

$$c_f + c_f^\star = y_f = F(m^\star, \ell_f). \tag{1.25}$$

6. The primary commodity market clears:

$$m + m^\star = y_c = \int_{\bar{A}}^{A_{\max}} A_j f(\ell_j) \phi\left(dA_j\right). \tag{1.26}$$

7. Labor markets clear:

$$\int_{\bar{A}}^{A_{\max}} \left(\ell_j + \frac{f}{\mu}\right) \phi\left(dA_j\right) + \ell_d \leq \bar{L} \tag{1.27}$$

$$\ell_f \leq \bar{L}^\star. \tag{1.28}$$

1.5.3 The role of idle resources and fixed cost externality

Before examining the results, let's consider an alternative specification of the primary commodity sector. First, assume all producers are equally productive, which is equivalent of having one representative producer. In that case, the measure of active 'firms' is always a degenerate measure that takes either the value 1, in case profits are nonnegative, and 0, otherwise. As a consequence, the fixed cost externality does not play any role because the representative producer either incurs the whole fixed cost either pays (and produces) nothing.

This specification brings us back to Section 1.4. To see that, note that since all primary commodity producer j's productivities are equal, say A_c, we have a unique representative producer problem in that sector:[11]

$$\begin{aligned} &\max_{\ell_c}\ p_c y_c - w\left(\ell_c + f\right) \\ &\text{s.t.}\ \ y_c \leq A_c \ell_c^{\gamma}. \end{aligned} \tag{1.29}$$

We can write a country's real GDP as follows:

$$\begin{aligned} RGDP_t &= p_{d,0} y_{d,t} + p_{c,0}\left(y_{c,t} - c_t^c\right) \\ &= p_{d,0} F(m, \ell_d) + p_{c,0}\left(f(\ell_c) - c_t^c\right), \end{aligned} \tag{1.30}$$

notice that its derivative with respect to the primary commodity price assumes the same form as in section 1.4, that is

$$\frac{\partial RGDP_t}{\partial p_{c,t}} = p_{d,0}\left[F_m(m, \ell_d)\frac{\partial c_t^c}{\partial p_{c,t}} + F(m, \ell_d)\frac{\partial \ell_{d,t}}{\partial p_{c,t}}\right] + p_{c,0}\left(f'(\ell_c)\frac{\partial \ell_{c,t}}{\partial p_{c,t}} - \frac{\partial c_t^c}{\partial p_{c,t}}\right). \tag{1.31}$$

Without the productivity differentials (and the subsequent existence of idle resources in equilibrium) and the fixed cost externality, this specification collapses to the same one as in Section 1.4. In this case, terms of trade nor primary commodity prices affect output and the data evidence remains unexplained. Under the model specification of the previous subsection, the productivity differentials induce the existence of idle resources, thus creating an extra term in Equation (1.31) relative to the new mass of primary commodity producers. Furthermore, the new measure of active producers in that sector changes the fixed production cost to be payed by each producer, changing the marginal conditions for all producers in the sector. As a result, the gains from reallocating labor input to that sector are not completely offset by the reduction of final good production.

1.6 Numerical experiment

In the remaining of the paper, I perform a numerical experiment to investigate the model's ability to reproduce the patterns in the data. For the calibration, I use moments relative to the Australian economy using data from the Australian Bureau of Statistic (ABS).

The home bias in consumption parameter, ω, is fixed at 0.7 to match the share of domestic goods on private consumption. I take σ from the literature to be 2 (see Ruhl, 2008). I normalize the productivity in the domestic sector, A_d, to 1 and set that of the most

[11] Without loss of generality, assume the parameters of the economy are such that the primary commodity sector is always active. Notice that, since all producers are the same, this is equivalent to an economy where there is no idle resources.

productive primary commodity producer, $A_{\max}$, to be so that the ratio $A_{\max}/A_d$ is equal to the observed ratio of the labor productivities of the primary sector over the whole economy, both measured in nominal gross value added per hour worked in the respective sector. Table VI presents the values of the parameters for both the two-country and the SOE cases.

1.6.1 Two-country economy

I perform steady state comparisons for the two-country economy model following a 1% increase in the non-PCX country productivity. A productivity increase in final sector of the non-PCX country is expected to increase the demand for commodity inputs in that sector, driving up the international equilibrium price of the primary commodity. In the PCX economy, this higher relative price of commodity induces, on one hand, a larger production of primary commodities and, on the other hand, a lower demand for commodity inputs by the domestic final sector. As a result, the PCX expands its exports of primary commodity and its output in the primary sector, while contracting its output in the final sector. Within my framework, the possibility of incorporation of former idle natural resources and the lower fixed cost burden in the primary commodity sector allows real GDP to increase.

Table VII summarizes the findings.

1.6.2 Small open economy

I consider a SOE otherwise similar to the PCX economy calibrated above. I use the autocorrelation and the standard deviation of the price of Australian main primary commodity export, coal, and simulate 1000 price shocks for a sequence of economies with different primary sector productivities. The benchmark case is still that with the ratio $A_{\max}/A_d$ equal to the observed ratio of the labor productivities of the primary sector over the whole economy. Then I allow $A_{\max}$ to vary around that observed ratio at increments of 0.1 to check how the correlation between terms of trade and real GDP interact with the share of primary commodity exports in total exports.

Figure 1.6 illustrates the results for this sequence of economies. Despite the fact that this result emanates from a preliminary calibration, that is, I did not match each country specifically besides Australia, the model does a good job mimicking the negative relation seem in Figure 1.5. The correlation for the economy that corresponds to the Australian productivity ratio is equal to -0.26, while its share of primary commodity exports in total exports is 87%.

1.7 Conclusion

In this paper, I define primary commodities as goods directly extracted from natural resources that have been minimally processed. According to this definition and the share of primary commodities in a country's export composition, I classify 46 countries into either primary commodity exporter (PCX) or non-PCX countries. Using quarterly data for the period 1990 to 2015, I find that each group of countries displays a particular behavior in the business cycles with respect to primary commodity prices and macroeconomic fundamentals. Additionally, the relations found are strengthened with an increasing share of primary commodities in total exports for PCX countries and a decreasing share for non-PCX countries.

In particular, the larger that share is for a PCX country, the more negative is the correlation between its terms of trade fluctuations and its most exported primary commodity price fluctuations. The same holds for the correlation between terms of trade fluctuations and real GDP fluctuations. In contrast, non-PCX countries display the opposite pattern. Furthermore, I show that both developed and developing PCX countries display the same patterns whereas much of the existing literature on primary commodities and terms of trade focuses on developing countries, particularly motivated by the fact that developing economies have historically performed the role of colonial providers of primary commodities.

Since standard models are unable to generate real aggregate fluctuations from price shocks if real GDP is correctly measured, this paper identifies a puzzle. I then propose a class of mechanisms that is capable of explaining the heterogeneous impact of terms of trade fluctuations across countries. I exemplify how this class of mechanisms works with two ingredients to be incorporated in the standard model, idle resources and externalities.

As the empirical evidence suggests that any theoretical attempt to understand the fluctuations in PCX countries must incorporate features of the primary commodity sector, I explore two of these features that stand out: i) natural resources with different productivity levels and ii) large fixed costs for establishing an infrastructure that benefits all producers. I map each of these characteristics into one of the ingredients above, and then I build a model that successfully accounts for the behavior of terms of trade and its relation to real GDP for different export compositions.

Table I: Standard deviation of primary commodity price and consumer price index for selected countries (PCX and the USA)

Country	Main exported commodity	std($P_{\text{commodity}}$)	std(CPI)
ARG	Soybean meal	33.37	52.65
AUS	Coal, coke and briquettes	32.02	16.89
BRA	Iron ore and concentrates	36.95	30.11
CAN	Crude petroleum and oils	42.85	12.85
CHL	Copper	34.65	25.89
COL	Crude petroleum and oils	42.85	18.98
CRI	Bananas	27.58	37.48
DNK	Meat of swine, fresh, chilled, or frozen	28.83	13.42
GRC	Olive oil	26.82	22.21
IDN	Crude petroleum and oils	42.85	39.35
ISL	Fish, crustaceans, mollucs, preparations	28.79	24.53
MAR	Fish, crustaceans, mollucs, preparations	28.79	13.03
NOR	Crude petroleum and oils	42.85	13.33
NZL	Dairy products and birds' eggs	28.83	14.45
USA	Vegetables and fruit	24.71	15.60
ZAF	Coal, coke and briquettes	32.02	32.03
	All commodities and energy	35.94	

Note: For Argentina, the producer price index was used instead of the consumer price index. For Chile, the wholesale price index was spliced in with the consumer price index for the missing years. For the United States, the commodity price corresponds to an index of prices of "food" commodities.

Table II: Export composition and GNI per capita (average 1990–2015)

Code	Country	% commodities in exports			GNI per capita
		All	First	Second	(current US$)
ARG	Argentina	58.2	11.4	8.1	7,449
AUS	Australia	63.0	13.5	10.1	32,275
AUT	Austria	5.4	1.1	0.7	35,272
BEL	Belgium	8.2	2.0	1.1	33,787
BRA	Brazil	41.3	7.6	5.0	5,772
CAN	Canada	22.2	8.1	1.7	31,789
CHE	Switzerland	7.3	4.5	1.8	56,628
CHL	Chile	43.0	16.8	8.7	7,269
COL	Colombia	61.8	25.2	10.3	3,560
CRI	Costa Rica	41.2	11.1	7.0	5,114
CZE	Czech Republic	6.6	1.5	0.8	11,270
DEU	Germany	4.5	0.8	0.6	33,927

Table II: (continued)

Code	Country	% commodities in exports All	First	Second	GNI per capita (current US$)
DNK	Denmark	24.0	6.8	3.8	43,276
ESP	Spain	14.4	6.7	1.3	21,774
EST	Estonia	14.0	2.2	2.1	12,116
FIN	Finland	3.4	0.7	0.6	34,721
FRA	France	10.2	1.4	1.2	32,135
GBR	United Kingdom	10.3	4.9	1.5	32,025
GRC	Greece	25.8	2.8	2.5	17,984
HKG	Hong Kong	21.1	19.3	0.7	27,879
HUN	Hungary	10.6	2.8	1.9	8,639
IDN	Indonesia	35.6	10.1	5.45	1,543
IND	India	16.9	2.3	5.4	763
IRL	Ireland	8.9	3.4	2.1	31,640
ISL	Iceland	60.0	53.4	5.1	36,614
ISR	Israel	5.0	2.5	0.9	21,509
ITA	Italy	5.3	1.9	0.5	27,686
JPN	Japan	1.0	0.3	0.2	37,330
KOR	South Korea	2.6	1.0	0.8	16,018
LTU	Lithuania	17.0	3.7	2.1	8,823
LUX	Luxembourg	7.1	2.3	1.1	54,621
LVA	Latvia	18.5	4.0	3.0	9,612
MAR	Morocco	31.6	10.8	9.3	1,975
MEX	Mexico	19.2	12.3	2.8	6,760
NLD	Netherlands	15.5	3.3	2.6	37,030
NOR	Norway	48.0	38.2	6.2	57,953
NZL	New Zealand	38.6	19.3	14.1	22,308
PHL	Philippines	12.4	2.9	2.3	1,715
POL	Poland	14.1	4.0	2.5	7,629
PRT	Portugal	7.8	1.4	0.05	15,565
SGP	Singapore	2.3	0.3	0.3	30,587
SVK	Slovakia	4.5	0.5	0.4	11,306
SVN	Slovenia	5.5	1.3	0.07	18,237
SWE	Sweden	4.4	0.9	0.9	40,739

Table II: (continued)

Code	Country	% commodities in exports All	First	Second	GNI per capita (current US$)
THA	Thailand	20.5	5.8	3.4	3,179
TUR	Turkey	15.0	7.2	1.4	5,886
USA	United States	12.2	1.2	1.1	39,799
ZAF	South Africa	25.6	6.4	3.6	4,640
	Average	21.3	8.0	3.9	20,411

Table III: Terms of trade and real commodity prices statistics

Statistic	Group of countries PCX	Non-PCX	All countries
Panel A: Terms of trade (log)			
St. dev.	0.1902	0.0910	0.1399
Mean	4.6893	4.6107	4.6386
ρ	0.9521	0.8751	0.9420
st(ρ)	(0.0083)	(0.0094)	(0.0052)
R^2	0.9596	0.9105	0.9452
Observations	1442	2622	4064
Panel B: Commodity prices (log)			
St. dev.	0.5607	0.4672	0.5103
Mean	4.2164	4.4010	4.3350
ρ	0.9288	0.9563	0.9453
st(ρ)	(0.0100)	(0.0057)	(0.0051)
R^2	0.9643	0.9797	0.9727
Observations	1442	2590	4032

Note: The estimating equation for the persistence parameter is $p_t = \mu + \gamma t + \rho p_{t-1} + \epsilon_t$.

Table IV: Average statistics by country groups

Statistic	Group of countries PCX	Non-PCX	Developing	Developed
Std(P_{comm})	0.159	0.109	0.145	0.115
Std(ToT)	0.053	0.025	0.043	0.023
Std(GDP)	0.022	0.019	0.024	0.017
corr(ToT,P_{comm})	-0.330	0.170	-0.145	0.095
corr(ToT,GDP)	-0.190	0.160	-0.067	0.1740

Note: P_{comm} denotes the price of the most exported primary commodity.

Table V: Coefficients by country groups

Category	Coefficient	St. Dev.	P statistic
Developed non-PCX	0.181	0.030	0.000
Developed PCX	-0.048	0.021	0.022
Developing PCX	-0.069	0.016	0.000
Developing non-PCX	-0.007	0.020	0.696
Constant	0.000	0.000	0.846

Note: The associated regression is
$gdp_{i,t} = \alpha_0 + \sum_{i=1}^{48} \sum_{j=1}^{4} \alpha_j D_{i,j} ToT_{i,t} + \varepsilon_t$.

Table VI: *Preliminary* calibration

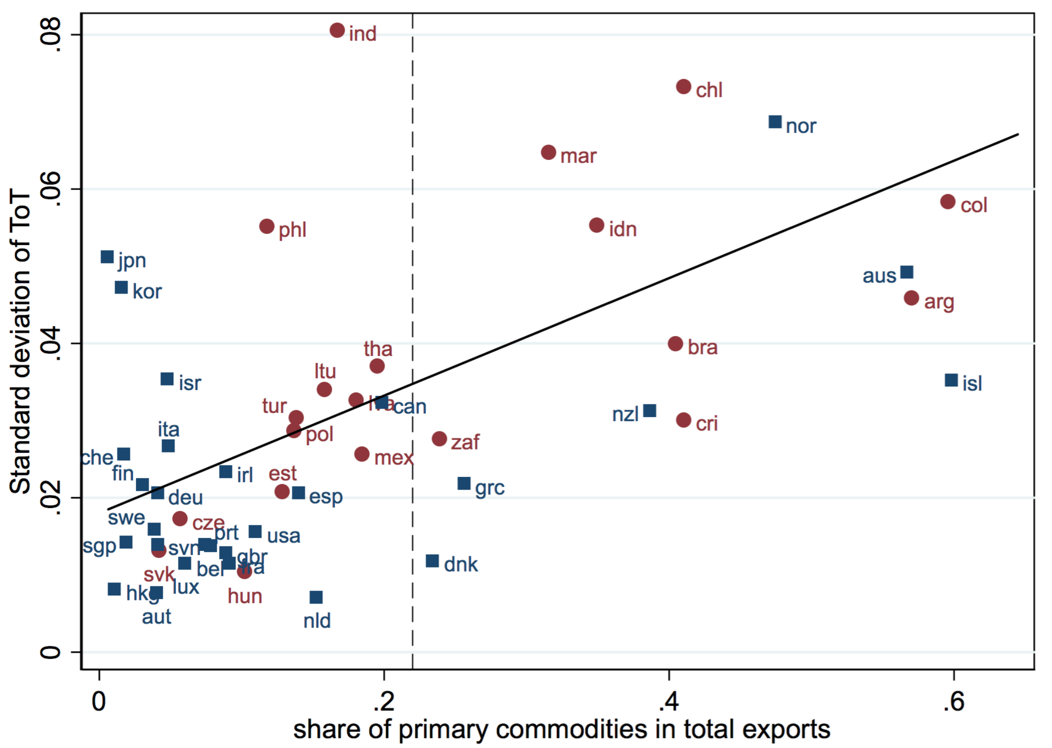
Parameter	Symbol	Value	Counterpart
Labor endowment	$\bar{L}$	10.0	
Elasticity of substitution	σ	2.0	Ruhl (2008)
Home bias in consumption	ω	0.7	Domestic absorption/imports
Final good productivity	A_d	1.0	Productivity normalization
Commodity share	α	0.1	
Commodity productivity	$A_{\max}$	4.5	Primary sector/economy productivity
Labor share	γ	0.5	
Fixed cost	f	0.25	
Foreign final good price	p_f	1.0	Price normalization
Small Open Economy only			
Price ratio domestic/commodity	p_d/p_c	1.45	

Table VII: Two-country model – variations for a 1% increase in non-PCX productivity

Variable	Commodity exporter	Non-commodity exporter
Real GDP	0.05%	11.15%
Terms of trade	−4.65%	4.88%
Commodity price	5.40%	5.40%
Measure of commodity producers	−1.55%	− − −
Commodity share in exports	1.20%	− − −
Nominal GDP	4.56%	10.52%

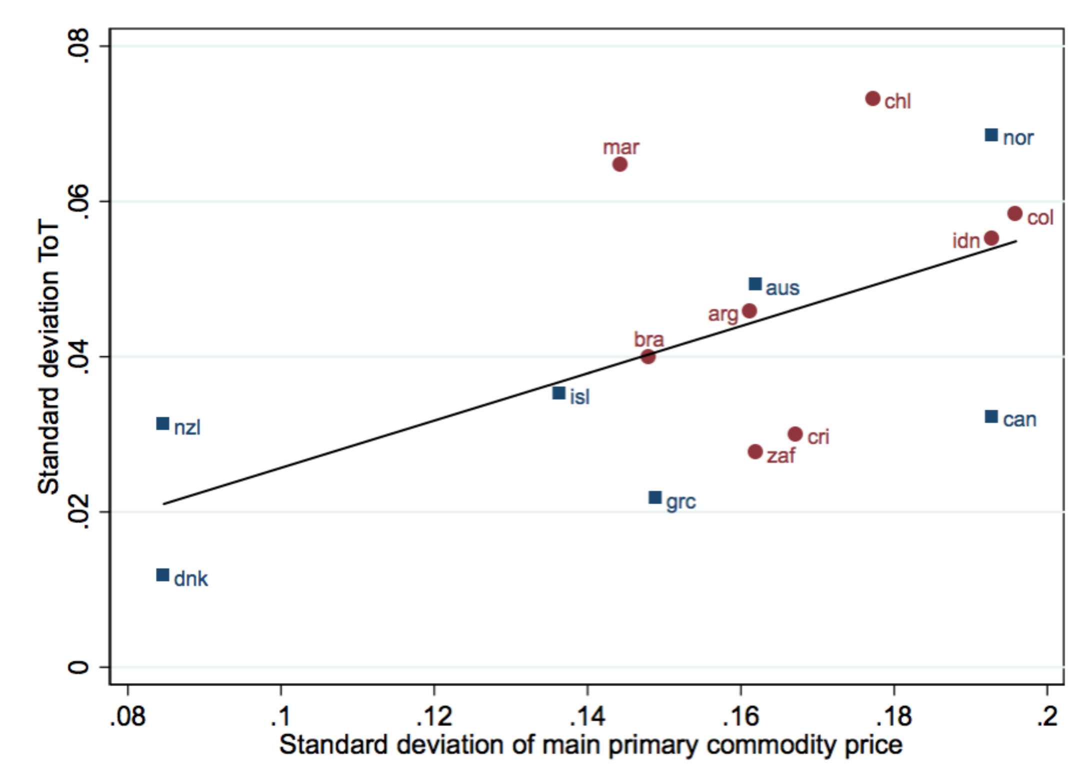
1.8 Figures

Figure 1.1: Standard deviation of terms of trade for PCX and non-PCX



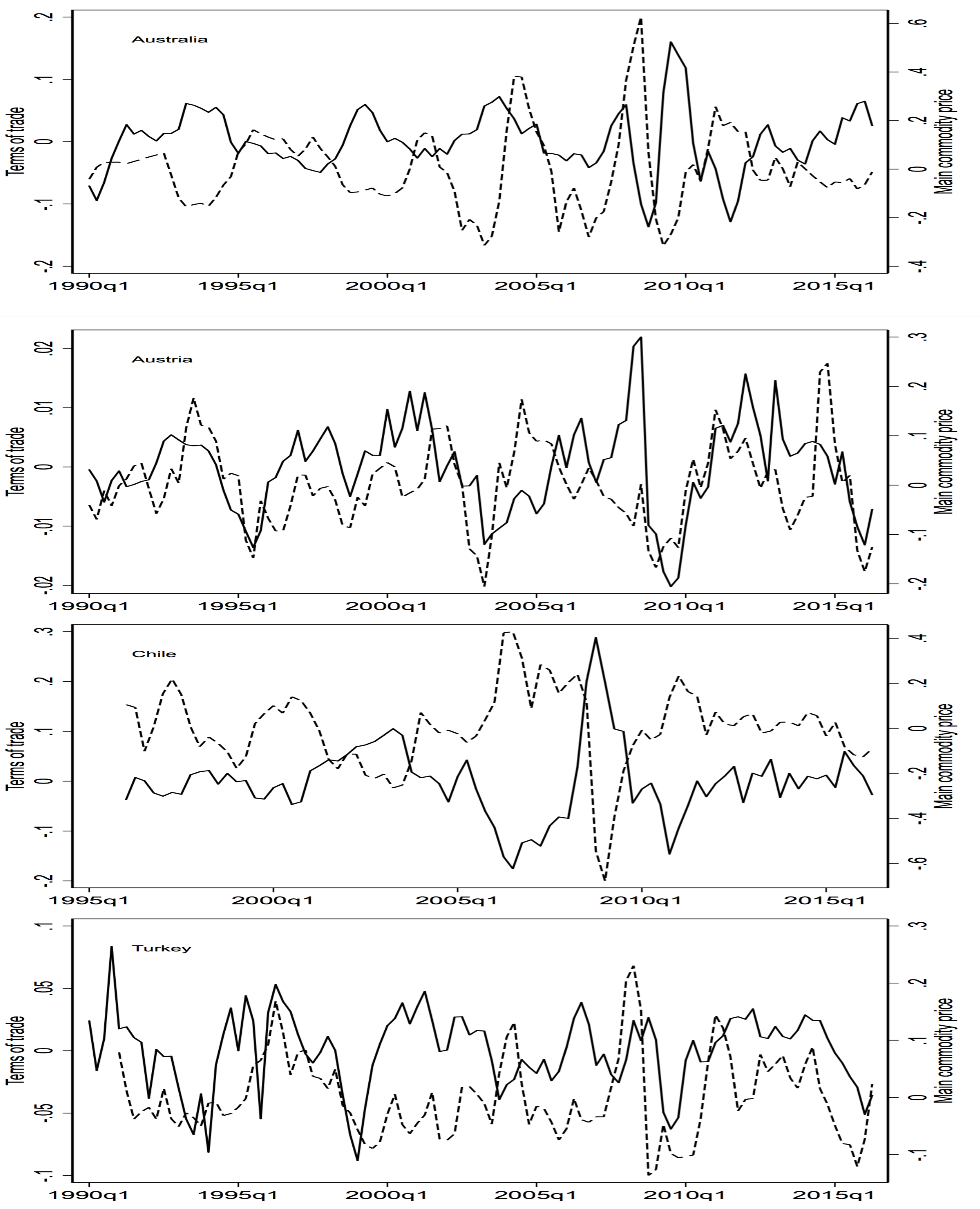
Note: High-income countries (GNI per capita of US$12,616 or more, according to the World Bank criterion) are designated by a blue square, while low-income countries are red circles. Figure A.1 has countries with annual data. The dashed vertical line is the threshold above which a country is a PCX.

Figure 1.2: Standard deviation of commodity prices and terms of trade for PCX



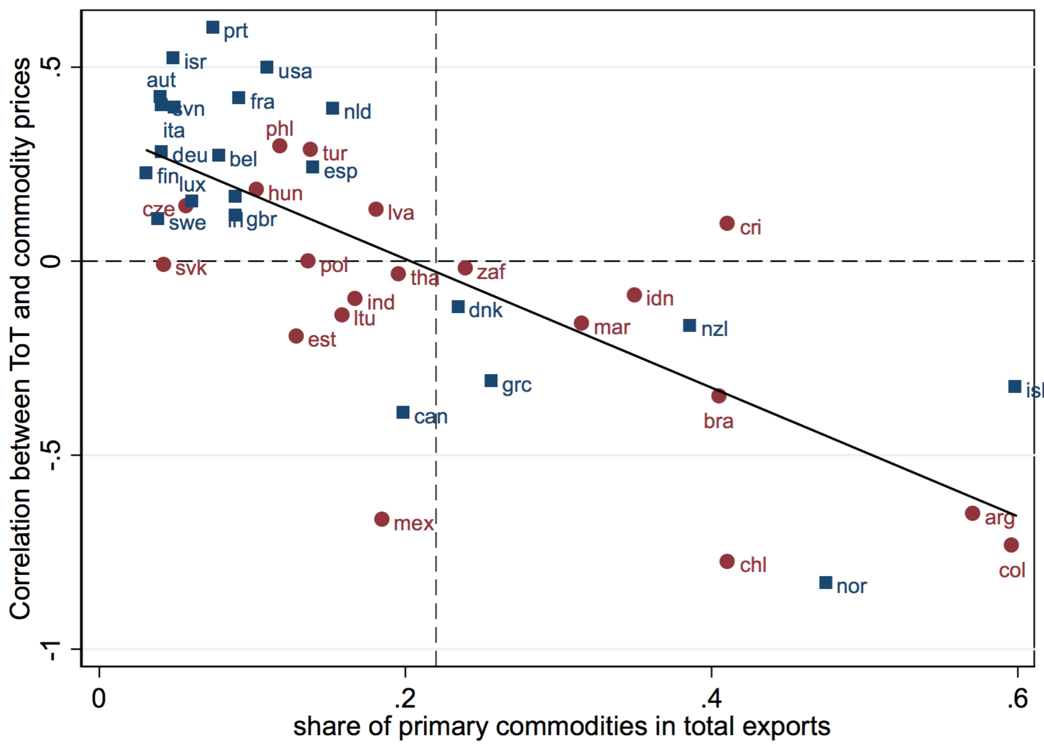
Note: High-income countries (GNI per capita of US$12, 616 or more, according to the World Bank criterion) are designated by a blue square, while low-income countries are red circles.

Figure 1.3: Commodity prices and terms of trade for Australia, Austria, Chile, and Turkey



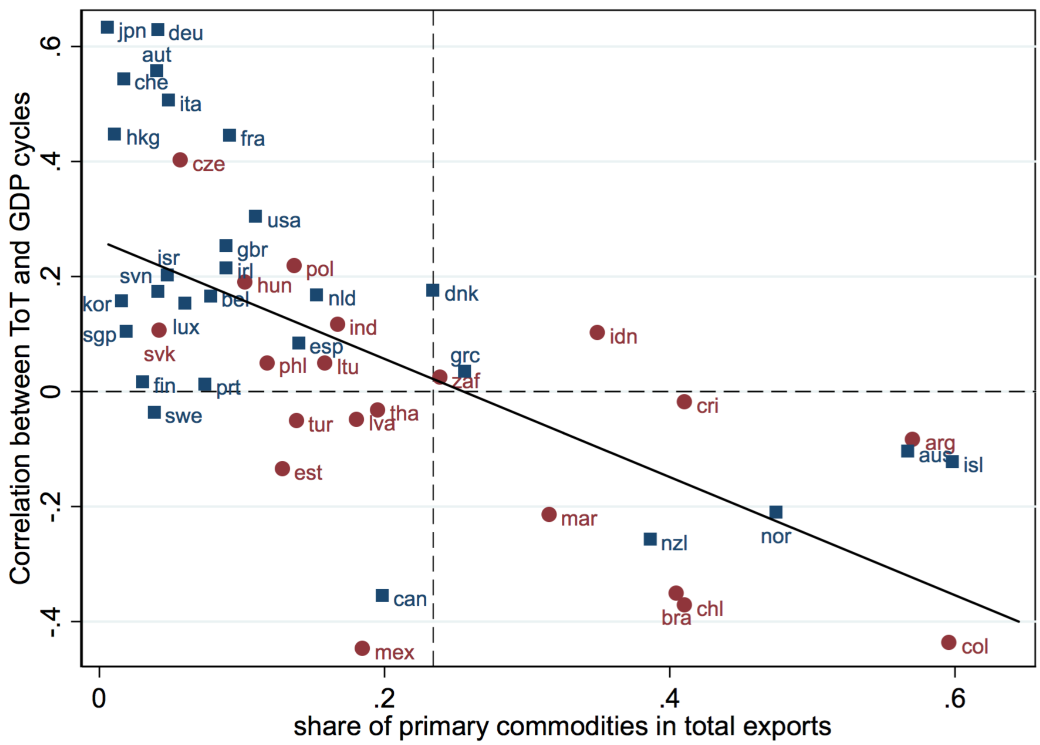
Note: The figure presents the terms of trade (solid line, left axis) and the price of the most exported commodity (dashed line, right axis) for Australia (panel 1), Austria (panel 2), Chile (panel 3), and Turkey (panel 4).

Figure 1.4: Correlation between terms of trade and primary commodity prices



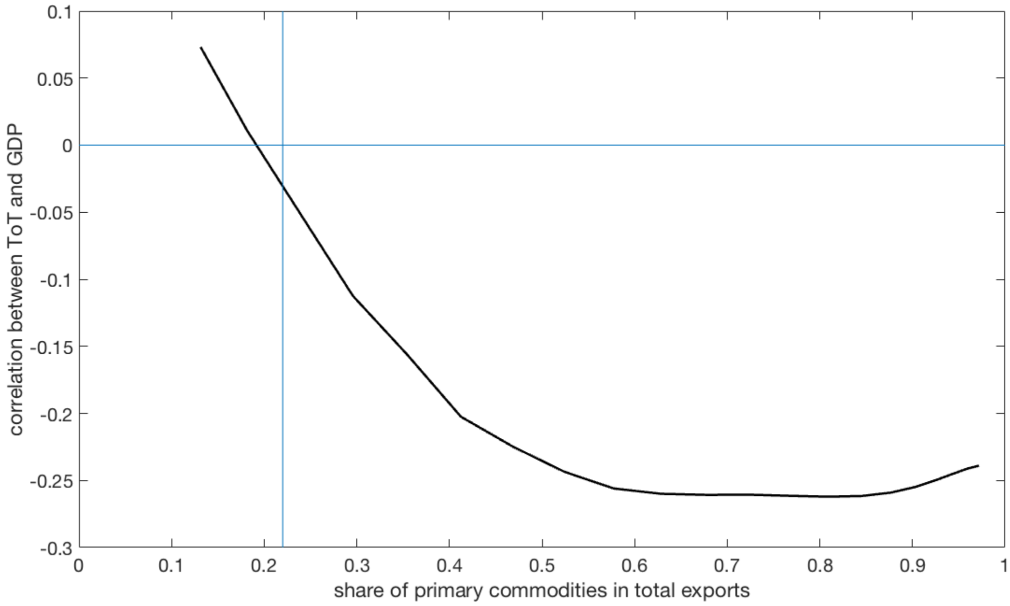
Note: High-income countries (GNI per capita of US$12,616 or more, according to the World Bank criterion) are designated by a blue square, while low-income countries are red circles. The dashed vertical line is the threshold above which a country is a PCX.

Figure 1.5: Correlation between terms of trade and real GDP



Note: High-income countries (GNI per capita of US$12,616 or more, according to the World Bank criterion) are designated by a blue square, while low-income countries are red circles. The dashed vertical line is the threshold above which a country is a PCX.

Figure 1.6: Correlation between terms of trade and real GDP - SOE model



Chapter 2

North-North Migration and Agglomeration in the European Union15

2.1 Introduction

In light of current selective migration reforms, this paper revisits empirical evidence on migration within the European Union 15[1] (EU15), disaggregated by occupation. We document that foreign-born workers within this area live in countries where their type is relatively more abundant among natives. This is at odds with traditional models of migration. We build a model with a sector exhibiting external economies of scale that allows for international labor flows between countries that are similar both in terms of income and individual characteristics of workers. The main result is that, if a country has a relatively larger fraction of native population working in a high educated intensive sector, this country will attract foreign labor of the same type. This is consistent with migration patterns observed in high-educated occupations in our sample of analysis.

The share of total immigrants relative to the population in Europe is now similar to that of the United States (US), though that number was much smaller around 1960 (Dustmann and Frattini, 2012). Regardless of the migratory inflows generated by the decolonization process and the incorporation of Eastern European countries to the European Union (EU), 20% of the immigrants in the EU15 are native from other EU15 countries. Recent policy changes are likely to be behind these numbers. Two examples of these changes are: the creation of a free mobility area, established by the consolidation of the Schengen Area in 1995, and the changes in national policies that formalize agreements reached under the framework of the European Higher Education Area (EHEA).

The EHEA is the result of a series of agreements signed between 1999 and 2009, involving changes in national educational policy by the member states[2]. These changes include the transferability of academic credits and the mutual recognition of degrees across the EHAE. While the Schengen Area is just one of many labor free mobility areas in the OECD (OECD, 2012), the EHEA represents the first *human capital free mobility area*. For our analysis, this means that, nowadays, skills are more transferable and workers are more mobile within this area, which enhances the importance of the intra EU migration phenomenon. These two types of free mobility policies, of workers and skills, are likely to reinforce each other.

Selective migration policies have gained weight, among industrialized countries, in detriment of traditional quotas and family reunification. This type of policies favor inflows of highly skilled labor. Within the EU, for instance, the United Kingdom is considering adopting a point-based immigration scheme, where potential immigrants earn points on the basis

[1] The EU15 comprised the following 15 countries: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, United Kingdom.

[2] All European countries except for Belarus are part of the EHEA.

of their qualifications and skills, among other factors. More recently, the Great Recession has brought up concerns that were not present at the time the free mobility agreements were signed.

Most models that examine migration analyze migration flows from poorer regions, where a type of labor is abundant, to richer regions, where it is scarce. We relegate the discussion of these types of models and its by-products to the next subsection, in relation to their main references. We refer to this approach as the *south-north* approach. In this setup, immigrants can have higher expected earnings abroad, because of differences in countries' income levels or because of the relative scarcity of their type of labor as compared to the host country. We will show that this is not the case between workers of the EU15.

Using data from the European Labor Force Survey, we find that, if a EU15 country has a relatively larger fraction of native population working in a high-educated occupation, this country will attract foreign EU15 labor of the same type. We also document that high-educated occupations display concentration patterns in the sense that workers in those occupations tend to cluster in specific countries.

We develop a model with external economies of scale where wages are strictly increasing in the amount of high-educated (HE) labor, both foreign and native, employed in a country. Hence, at the individual level, it is worthy for the most able households to become HE and to move to the country where there are more HE native workers. This is consistent with the migration patterns observed in high-educated occupations in our sample of analysis, which we refer to as *north-north* migration patterns. Therefore, by incorporating the previously described agglomeration mechanism, the model we propose in this paper successfully generates the EU15 migration flows and concentration patterns for our sample data.

The paper is organized as follows. Section 2 discusses some of relevant literature in migration related to our paper. Section 3 describes the data and documents patterns of intra-EU15 migration by occupation. Section 4 describes the model and the equilibrium. Section 5 reports and discusses the results. Section 6 concludes.

2.2 Related Literature

A large proportion of the literature on migration focuses on migration flows from low income (south) to high income (north) countries. An emblematic case is the US-Mexico migration. In this literature, individuals migrate because of the relative scarcity of their own type of labor in the host country, which rewards those that cross the border with higher labor earnings. International labor flows generate a reallocation of labor that is jointly determined by the demand and the supply of both native and foreign workers. Once net wages equalize in both countries, this approach predicts that migration flows will cease. We refer to this approach as the south-north approach.

Recent policy changes have driven attention to a different type of labor flows where workers migrate to countries similar to their source country and where their type is relatively more abundant. We refer to this as north-north migration. This type of flows can not be explained by the south-north literature because its basic mechanism is contradicted from the beginning. This section reviews some of the migration literature in line with the south-north traditional approach and point to where they fail to explain and predict the intra-EU15 flows.

A new generation of migration models was born when self-selection of immigrants and brain drain started to gain importance. A seminal work in self-selection of immigrants is Borjas (1994). In his model, self-selection is driven by the correlation between skills across countries and their relative earnings distribution dispersion. With this model, Borjas aims to explain migration flows towards the United States and the differences in the earnings of immigrants by country of origin. Moreover, immigrant cohorts from the same source country might differ according to changes in the relative rate of return to skill. Despite his claim that his model is able to explain migration flows for many host countries, this is only true when the host country is relatively richer than the source country.

Urrutia (2001) goes a step further in this line of thought and models migration flows from Mexico and India to the US in a south-north approach. He extends the analysis allowing for differences in migration costs due to distance and language barriers, that he models as a fixed cost and as a temporary loss of ability respectively. By considering these two aspects, Urrutia generates a self-selection pattern that can account for heterogeneity in the performance of immigrants from different source countries, which is observed in the data. His main result is that immigrants from distant countries are more likely to belong to the top abilities distribution. This result goes in the opposite direction to the one we are interested in this paper, where migrants from and to EU15 move across proximal countries and yet belong to the top abilities distribution for some occupations.

Lopez-Real (2011) incorporates a new source of heterogeneity of workers. In his model, workers are heterogeneous in years of schooling and ability. Lopez-Real finds that self-selection in ability is always positive and that differences in TFP determine whether self-selection in schooling is positive or negative. Nonetheless, his model cannot explain the concentration we document among EU15 countries. Moreover Lopez-Real assumes the host country is a large open economy while the source country is a small open economy. This is not the case for EU15 countries since they are similar in terms of size and openness.

Dustmann and Frattini (2012) provide an overview of immigration to Europe from the Second World War to the early 2010s. The authors document the existing disparities between immigrants born in the EU and those born outside of the EU, with special focus on labor markets. Overall, they find that EU immigrants are more similar to the native population than immigrants from elsewhere. For instance, EU immigrants are more similar to natives with respect to occupational and educational attainment distributions. Non-EU immigrants are found to be more concentrated than EU nationals in less skilled occupations. Hence their observations support our evidence that the intra-EU migration flow differentiates itself from the aggregate migration flow to the EU15 countries in a peculiar way: a large fraction of it mimics the characteristics of the national population, with some exceptions.

Dustmann and Frattini (2012) calculate the employment probability for those groups controlling for gender, education, region and age. They conclude that non-EU immigrants are in disadvantage in all countries studied, lagging behind by at most 20 percentage points in employment probability compared to natives with the same characteristics. Meanwhile EU immigrants are at most 8 percentage points behind. The differences across immigrants documented in their work foster relevant questions that are left unanswered by the traditional south-north literature. Why are migration flows across EU15 countries more intense than what is predicted by the south-north models provided that those countries are considerably more homogeneous? Why do the EU15 migrants are so different from those coming from other parts of the world?

The model of this paper is based on Chipman (1970). For our model, the most important feature of his theoretical framework is the presence of increasing returns to scale in the production of the skilled intensive good, that are external at the firm level. This is the main force that induces agglomeration of workers with similar characteristics after migration. In this paper, we use the aforementioned feature and generalize the model of Haupt and Uebelmesser (2010), which focus on high-educated flows, by creating a second sector with a constant returns to scale (CRS) technology, and by having a general equilibrium environment. We incorporate features of their model by allowing households to simultaneously choose education and migration in the skilled intensive sector. In the future our aim is to open the migration option for workers in the CRS sector too, in order to generate heterogeneity of migration flows.

2.3 Data and Empirical Evidence

2.3.1 Data and Classifications

One of the main limitations of the analysis of migration patterns across different countries is the lack of comparable data. It is often the case that each country uses a different definition of immigrant based on either nationality or country of origin. Harmonized data on migration status and occupation for European countries are available from two sources: the European Labor Force Survey (EU-LFS), which consists of repeated cross-sections of individuals from 1983-2013; and the Database on Immigrants in OECD Countries (DIOC), which reports aggregate numbers of workers by different demographic and labor market categories based on Census data, with a comprehensive list of variables and countries only for the year 2001[3]. In this analysis, we use the EU-LFS and we consider a worker to be immigrant if she was born in a country different from the one in which she works.

The European Union Labor Force Survey Database

The European Union Labor Force Survey (EU-LFS hereafter) is a harmonized household sample survey that contains quarterly detailed information on individuals per country for 28 European countries. The data covers the years from 1983 onwards, due to availability of our variables of interest we keep the years of 1996 to 2010, for a total of 31,663,252 observations.

The core variables are country of residence, country of birth, educational attainment, employment status, hours worked and occupation. They use the the 1988 International Standard Classification of Occupations (ISCO-88 hereafter) to identify occupations. Out of the 28 countries available in the EU-LFS, we keep EU15 countries.

The ISCO-88: Description and Relation to Educational Classification

The ISCO-88 is one of the occupational classifications published by the International Labour Office (ILO, 1990). It uses information on national coding for over 80 countries and organizes them into a standard classification of occupations.

Even though each occupation presents a different skill specialization content in terms of tasks,we find convenient is that its ordering coincides with its corresponding educational level. In particular, eight of the nine major ISCO-88[4] groups are ordered with reference to education levels[5] defined for ISCO-88 (See Table A.2 for a detailed description of each

[3]A version for 2005 is available, but the information disaggregated by occupation is incomplete for a large part of the countries.

[4]We exclude Armed Forces (group 0).

[5]The ISCO levels of education are based on the first (1976) version of the International Standard Classification of Education (ISCED). ISCO defines 4 levels of education: 1 for primary education, 2 for lower

group). Five out of nine major ISCO-88 groups (4, 5, 6, 7 and 8) have the same average education level (lower or upper secondary education). These five groups, together with Elementary Services (group 9)[6], will be considered *Low-Educated* in the analysis below. The remaining groups (1-3) include occupations that require tertiary education and therefore will be classified as *High-Educated*.

2.3.2 Empirical Analysis

This section is organized in three parts. In the first part, we provide empirical support our north-north approach showing that EU15 immigrants are different from non EU15. Henceforth we limit the study to foreign-born workers whose country of origin is a EU15 member. Then we focus on the distribution of foreign-born workers across occupations, compared to the distribution of native-born workers. In the second part, we compute the correlation between the occupational distributions of foreign-born workers and that of native-born workers, for each country. We use this correlation to explain the relation between natives and foreigners. Finally in the third part, we compute a proxy for concentration of total workers depending on their occupation. For this measure, we use the educational component of the ISCO-88. A detailed definition and explanation of these measures will be provided below.

North-North Empirical Analysis

Many authors[7] have emphasized the differences between EU15 immigrants and other foreigners. In particular, EU15 immigrants have similar characteristics as natives, for example both groups have high levels of education and are more concentrated in skilled occupations. Figure 2.1 depicts the distribution of employment across occupations, ordered by wage, for natives and foreigners. In line with previous findings, we observe that EU15 foreigners behave in a similar fashion as natives and very differently from non EU15 immigrants. Additionally, in panel (a) we observe that the share of EU15 foreigners exceeds that of natives in the top paid occupations. Panel (b) in Figure 2.1 shows the evolution of this distributions. Notice that this graph is reminiscent of the polarization literature: employment growth is larger in both tails of the wage distribution and negative in the middle, for natives and EU15 immigrants. We emphasize that both the share and growth rate of EU15 workers in the top paid occupations exceed that of any other group. In this paper we will concentrate on this particular group of occupations.

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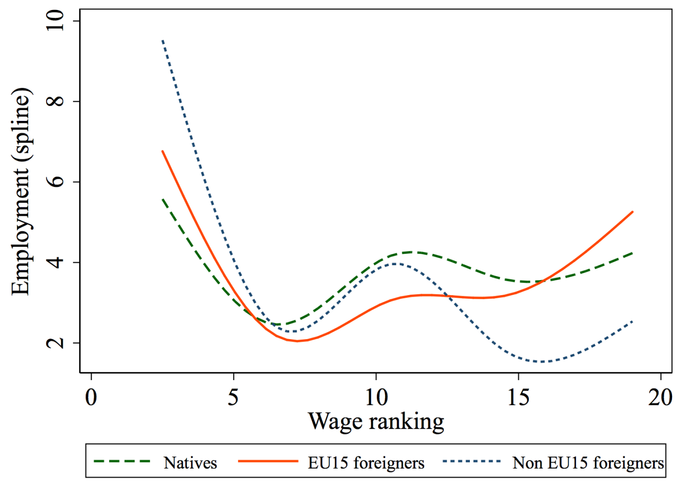
and upper secondary education, 3 for tertiary education not leading to a university degree and 4 for tertiary education leading to a university degree.

[6]Elementary Services is the only major group of occupations in which the average education level is primary school.

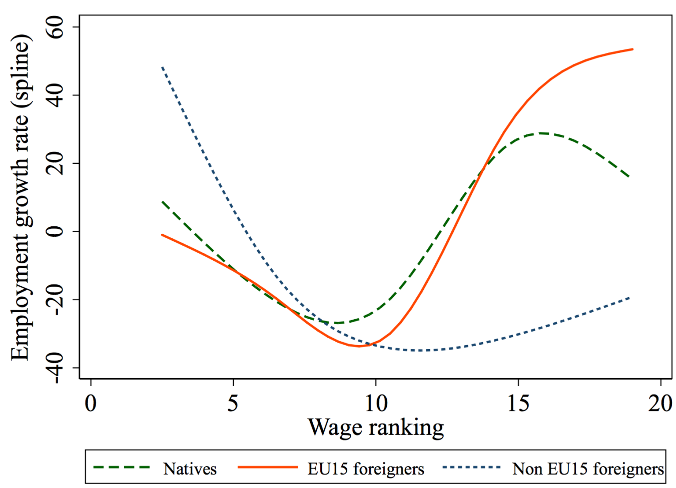
[7]Dustmann and Frattini (2012) among others, see references.

Figure 2.1: Employment distribution: Percentage (2010) and growth rate (1996-2010)

(a) Employment by migrant status



(b) Growth rate of employment (1996-2010)



Note: Wage ranking orders occupations by their mean wage across 10 European countries across all years, following wage information in Goos *et al.* (2014). We restrict the number of countries to match their wage ranking. Panel (a) plots the median spline of employment shares by migrant status, pooled across countries. Panel (b) plots the median spline of the growth rate of these employment shares from 1996-2010.For detailed information on occupations refer to Table A.1 in the appendix.

Occupational Migration Patterns

"Do people migrate to countries where there are more native workers of their type or where there are less?" This subsection addresses this question from an empirical perspective.

First, we define the occupational distribution of foreign and native workers in country i

as:

$$S_N^i = \left(s_{N1}^i, s_{N2}^i, ..., s_{NJ}^i\right), \text{ where } \quad s_{Nj}^i \equiv \frac{\#\text{ native workers in occupation } j \text{ and country } i}{\#\text{ native workers in country } i}$$

$$S_I^i = \left(s_{I1}^i, s_{I2}^i, ..., s_{IJ}^i\right), \text{ where } \quad s_{Ij}^i \equiv \frac{\#\text{ EU15-immigrant workers in occupation } j \text{ and country } i}{\#\text{ EU15-immigrant workers in country } i},$$

respectively, where J is the number of subgroups considered, $J = 26$ for the ISCO 2-digit.

Then, for each occupation j , we extract the shares by country for both native and immigrant workers: $(s_{Nj}^1, ..., s_{Nj}^I)$ and $(s_{Ij}^1, ..., s_{Ij}^I)$. Next, we compute the correlation between the occupational distribution of native workers and that of EU15 foreign-born workers. We interpret this as an empirical measure of how EU15 foreign-born workers allocate themselves across countries based on the given distribution of natives. More specifically, we regress S_N^i on S_I^i and a set of year dummies. Table I shows an example of how this shares look like for for subgroup 12 (Corporate Managers).

Table I: Share of Natives and Immigrants by Country of Residence

12: Corporate Managers, 2010

Country	Share Natives	Share Foreign EU-15
Austria	3.56	6.02
Belgium	7.40	14.12
Denmark	2.81	4.40
Spain	2.52	3.64
Finland	6.51	4.70
France	5.88	5.95
Greece	1.69	2.00
Ireland	9.08	14.60
Italy	2.09	2.75
Luxembourg	1.51	3.36
Netherlands	5.38	4.72
Norway	5.48	5.75
Portugal	2.07	3.98
Sweden	4.57	3.74
United Kingdom	12.07	11.53

Column 2 includes the ratio between the number of native-born workers in occupation 12 and the total number of native-born workers. Column 3 includes the ratio between the number of foreign-born workers in occupation 12 and the total number of foreign-born workers.

We obtain a correlation of 0.66, significant at the 1% level. As a comparison, this number is only 0.40 for immigrants from outside the EU15. The result of this empirical analysis is that if a country has a relatively larger fraction of native population working in a high-educated occupation, Managers in the example shown in Table I, this country will attract foreign labor of the same type.To answer the question that we posed at the beginning of the subsection, people do migrate to countries where there are more native workers of their type. This is an example of what we previously referred to as north-north migration patterns.

Concentration Patterns

"Do countries keep a balanced distribution of workers across occupations or are some groups of workers more concentrated in one country?" To answer this question, we present a measure of concentration of workers.

First, we define the occupational distribution of the total working population in country i as:

$$S^i = \left(s_1^i, s_2^i, ..., s_J^i\right), \text{ where } \quad s_j^i \equiv \frac{\#\text{ all workers in occupation } j \text{ and country } i}{\#\text{ all workers in country } i}$$

Recall that ISCO-88 occupations are ordered according to educational level. In the data description we have defined *high* and *low-educated* occupations. Notice that we can express S^i as $S_{HE}^i \bigcup S_{LE}^i$, where S_{HE}^i contains the shares corresponding to subgroups of groups 1-3, and S_{LE}^i those to subgroups of groups 4-9. Then, for each pair of countries in our sample, i and h, we compute $Corr(S_{HE}^i, S_{HE}^h)$ and $Corr(S_{LE}^i, S_{LE}^h)$, for each year of the sample. Then for each country i and year we compute the average (across education levels) of each pairwise correlation with the other countries in the sample. Finally we calculate the average across years.

We want to emphasize the difference with respect to the previous analysis. In this case, the population of analysis is total working population in each occupation, regardless of their country of birth. Second, this correlation is computed over the occupational distribution, by education group.

We interpret a positive correlation as evidence that the country keeps a balanced structure in that education group. A negative correlation means that a country has a lower share of its working population in occupations where other countries have a high share. We take this as evidence of concentration.

Table II presents the average correlations. We find two main results: First, for low-educated occupations, countries keep a more balanced structure, i.e., average correlations are positive and high in general. Second, for high-educated occupations, there are concentration patterns. In this occupation group, the results are more heterogeneous, yet correlations are generally lower and even negative for some cases.

Table II: Concentration Patterns (1996-2010)

Country	Average Correlation High Skill	Average Correlation Low Skill
Austria	.31	.75
Belgium	.34	.65
Denmark	.49	.76
Spain	.58	.69
Finland	.58	.68
France	.47	.77
Greece	.15	.39
Ireland	-.15	.79
Italy	.25	.66
Luxembourg	.57	.53
Netherlands	.58	.76
Norway	.38	.64
Portugal	.45	.44
Sweden	.57	.67
United Kingdom	-.43	.74

We will use these two main findings of education and concentration as input in our model. We will have two sectors: One will exhibit constant returns to scale and employ only low-educated labor. The other one will exhibit increasing returns to scale and employ only high-educated workers.

2.4 The Model

Framework

We consider a static, one-period model of education and migration choice. An economy consists of firms, households and governments. There are two countries: 1 and 2. Both countries have identical production technologies and initial size. We normalize initial population size to 1 in each country.

There are two productive sectors in each country: one displays constant returns to scale (CRS) and the other one increasing returns to scale (IRS) at the industry level, i.e. IRS are external to the firm. They produce using High-Educated (HE) and Low-Educated (LE) labor, respectively.

Households are heterogeneous in ability and mobility. They make consumption, education and migration decisions and they supply labor inelastically. Their education decision determines the type of labor they will supply (HE or LE) and their migration choice determines their country of residence. Finally, there is a government that collects education payments of high-educated workers and transfers them to households in a lump sum fashion.

We begin with a closed economy, in which there is no migration choice. Next, we analyze a two-country open economy model, where we allow for free mobility of goods, labor and degrees (skills)[8].

2.4.1 Closed Economy

Production

There are two goods in the economy: Y and Z. Sector Y is composed of a continuum of symmetric firms in the interval $[0,1]$ that use HE labor as their only input. Output of firm $k \in [0,1]$ is:

$$y_k = A(H) \cdot h_k, \quad \text{where} \quad H = \int_0^1 h_k dk, \tag{2.1}$$

where $A' > 0$, $A'' < 0$ and h_k is the amount of HE labor used by firm k.

Production of good Y exhibits IRS at the country-industry level, but these are external to individual firms. The more HE workers in the economy, the higher the output of each producer. However, each firm $k \in [0,1]$ is atomless and does not internalize its effect on aggregate demand of HE labor in their country. Therefore, each individual firm considers the productivity term in the production function as a constant and behaves competitively. Inverse demand of HE workers is given by:

$$w_H = A(H) \cdot P_Y \tag{2.2}$$

For simplicity, and since firms are identical, we characterize the equilibrium using a representative firm that demands h and produces Y.

Good Z is produced by a representative firm. The only input for production is LE labor and it has the following CRS technology:

$$Z = B \cdot L, \tag{2.3}$$

where $B \geq 1$ and L denotes the amount of LE labor used.

[8] In order to capture the free transferability of academic credits and the mutual recognition of degrees across the EHAE.

The inverse demand for LE workers is given by:

$$w_L = P_Z \cdot B. \tag{2.4}$$

Households and Government

Households are heterogeneous in ability. They are born low educated and can decide to remain uneducated and earn w_L working in the CRS sector. Alternatively, they can choose to acquire high education by paying an individual specific cost[9] and then earn w_H working in the IRS sector. Regardless of their choice, they supply labor inelastically since there is no disutility from working.

At the beginning of the period, each household $j \in [0,1]$ makes an ability draw that determines her education cost θ_j, which is negatively related to ability. For the most able individual, education will be free. For the least able individual, the cost will be the highest possible cost, $\bar{\theta}$. Education costs are uniformly distributed in the interval $\left[0, \bar{\theta}\right]$.

Given ability, prices, wages and transfers $\left(\theta^j, P_Y, P_Z, w_H, w_L, T\right)$, each household j chooses an education level and consumption bundle $\left\{e^j \in \{HE, LE\},\ c_Y^j, c_Z^j\right\}$ to solve:

$$\begin{aligned}
\max_{\{e^j, c_Y^j, c_Z^j\}} \quad & \lambda \log c_Y^j + (1-\lambda) \log c_Z^j \\
\text{s.t.} \quad & P_Y c_Y^j + P_Z c_Z^j \leq W^j \\
& W^j = w_H - \theta_j + T \quad \text{if } e^j = HE \\
& W^j = w_L + T \qquad\quad\ \ \text{if } e^j = LE \\
& c_Y^j \geq 0, \quad c_Z^j \geq 0
\end{aligned}$$

The last agent of our economy is the government (G). This agent collects education payments and transfers them equally to all households in a lump-sum fashion . The revenue of the government is given by:

$$G^R = \int_{\mathcal{H}} \theta_j dj = \int_0^{\theta^*} \theta_j dF(\theta) = \int_0^{\theta^*} dF(\theta), \tag{2.5}$$

where F is the *cdf* of θ_j, $\mathcal{H} \equiv \left\{j \in [0,1] \mid e^j = H\right\}$ and θ^* is a threshold that characterizes the set of educated workers. We will elaborate further on this cutoff value in the next subsection. Government expenditures are equal to:

$$G^E = \int_0^1 T dj, \tag{2.6}$$

[9] In general, the education cost can be interpreted as effort or ability.

where T is the per capita transfer.

Definition 2.4.1 ***Autarky Equilibrium:*** *Given the ability distribution $U[0,\bar{\theta}]$, a competitive equilibrium for this economy is: (i) education and consumption choices from households: $\left\{\left(e^j, c_Y^j, c_Z^j\right)\right\}_{j\in[0,1]}$, (ii) production plans: (Z, L, Y, h), (iii) lump-sum transfers T, (iv) prices: $\{P_Z, P_Y, w_H, w_L\}$ and (v) an endogenous threshold θ^* such that:*

1. *Given prices, transfers the ability draw θ_j, (c_Y^j, c_Z^j, e^j) solves j's problem, $\forall j$.*
2. *Given prices, the production plan of the IRS sector, (Y, h), satisfies $w_H = A(H) \cdot P_Y$.*
3. *Given prices, the production plan of the CRS sector (Z, L) satisfies $w_L = B \cdot P_Z$.*
4. *Government budget balances:*

$$\int_{\mathcal{H}} \theta_j dj = \int_0^1 T dj$$

5. *Labor markets clear*

$$\begin{aligned} H^s &\equiv \int_{\mathcal{H}} j dj \\ H &\equiv h = H^s \\ H + L &= 1 \end{aligned}$$

6. *Goods markets clear*

$$\begin{aligned} Y &= \int_{\mathcal{H}} c_Y^j dj + \int_{\mathcal{H}^c} c_Y^j dj \\ Z &= \int_{\mathcal{H}} c_Z^j dj + \int_{\mathcal{H}^c} c_Z^j dj \end{aligned}$$

Characterization of the Equilibrium

Households consumption demand functions are:

$$c_Y = \frac{(\lambda)}{P_Y} \cdot W^j \tag{2.7}$$

$$c_Z = \frac{(1-\lambda)}{P_Z} \cdot W^j, \tag{2.8}$$

Given the ability draw θ_j, households maximize net labor income in order to maximize utility. Their education decision boils down to:

$$e^j = \begin{cases} HE & \text{if } w_H - \theta_j \geq w_L \\ LE & \text{otherwise} \end{cases} \tag{2.9}$$

This inequality determines individual supply of HE labor. Using the distribution of education costs $\theta_j \sim U[0, \bar{\theta}]$, we get an expression for aggregate supply of HE labor:

$$H = F(w_H - w_L) = \frac{w_H - w_L}{\bar{\theta}} \tag{2.10}$$

Notice that equation 2.10 implies that, all else equal, the higher the maximum cost of acquiring education, the smaller the share of HE people working in the IRS sector. We emphasize this result, since it will be the main difference between countries in the integrated economy. Note that the education decision is determined by a cutoff rule: every household j with $\theta_j \leq \theta^*$ will become HE, where $\theta^* = w_H^* - w_L^*$.

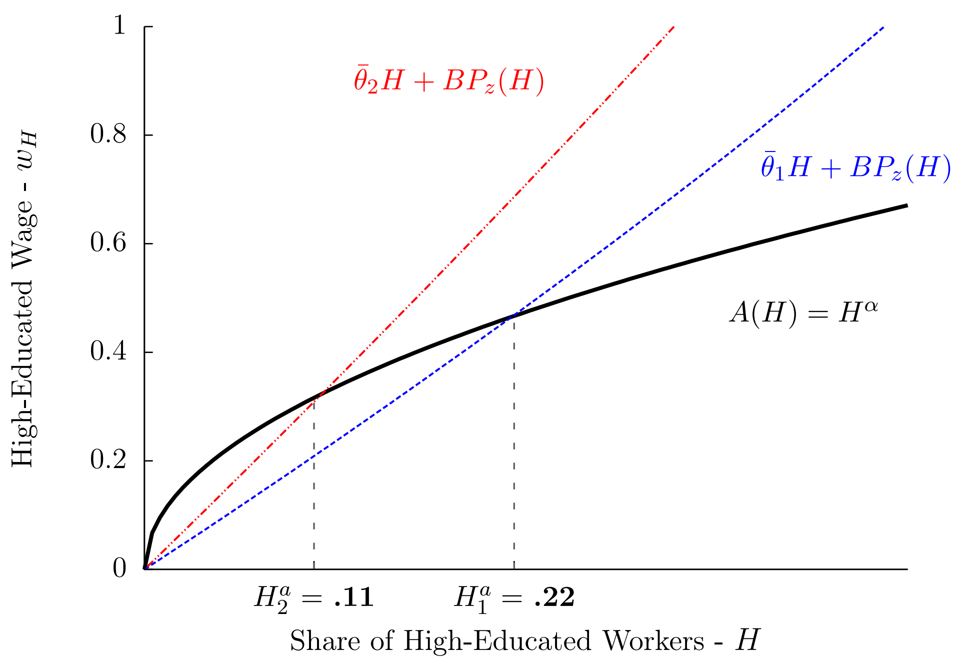
To complete the characterization of the equilibrium, we normalize $P_Y \equiv 1$. Combining the firm's inverse demand for labor and using the market clearing conditions:

$$H^* = \frac{A(H) - BP_Z^*(H)}{\bar{\theta}} \tag{2.11}$$

$$P_Z^*(H) = \frac{(1-\lambda)HA(H)}{\lambda B(1-H)} \tag{2.12}$$

In Figure 2.2, we illustrate the equilibrium under different ability supports. We use the following specification: $A(H) = H^\alpha$, $\alpha = 0.5$, $\lambda = 0.8$, $B = 1$, $\bar{\theta}_1 = 2$ and $\bar{\theta}_2 = 3$.

Figure 2.2: Autarky Equilibrium



2.4.2 Integrated Economy

We now consider an integrated world economy consisting of two countries indexed by i. Countries are identical in production technologies, preferences and population sizes, but differ in the distribution of ability. The world population is normalized to 2 (1 for each country). Both goods are tradable and both countries are big.

Households are heterogeneous in mobility and ability. In each country, there is an exogenous fraction $\gamma \in (0,1)$ that is perfectly mobile, and a fraction $(1-\gamma)$ that is perfectly immobile. Both types of labor, HE and LE, are perfect substitutes across countries. That is, natives and immigrants are assumed to be equally productive. The ability distribution is $\mathcal{U}\left[0, \bar{\theta}^i\right]$, where $\bar{\theta}^i$, $i \in \{1,2\}$, is now country specific. The distribution of ability is the same across mobile and immobile groups. People pay for education in their country of origin and can freely transfer their degree across countries.

Firms' problems in each country remain unchanged. Since both goods are perfectly tradable, prices will equalize across countries. This, together with the fact that the CRS sectors are identical, imply that wages of the low educated sector are also equalized across countries ($w_L^1 = w_L^2$).

In the open economy we have two types of households: mobile and immobile. Immobile ones face the same problem as in the closed economy. Mobile households, however, now have the additional choice of migration. More formally, a mobile worker j in country i chooses:

(i) Her education level: $e_j^i \in \{HE, LE\}$, which determines the sector where she will work.

(ii) Her migration status: $m_j^i \in \{N, M\}$, where N stands for *Native* and M for *Migrant*. This decision, given (i), determines her country of residence and, therefore, her wage.

Given mobility, ability, prices, wages and transfers $\left(\gamma, \theta_j^i, P_Y, P_Z, w_H^i, w_L^i, T^i\right)$, each household j from country $i \in \{1,2\}$ chooses an education level, a migration status and a consumption bundle: $\left\{e_j^i \in \{HE, LE\}, m_j^i \in \{N, M\},\ cy_j^i, cz_j^i\right\}$ to solve:

$$
\begin{aligned}
&\max_{\{e_j, m_j, cy_j, cz_j\}} \lambda \log cy_j^i + (1-\lambda) \log cz_j^i \\
&\quad s.t. \quad P_Y cy_j^i + P_Z cz_j^i \leq W_j^i \\
&\quad where \quad W_j^i = w_H^i - \theta_j^i + T^i \qquad \text{if } e_j^i = HE \quad m_j^i = N \\
&\qquad\qquad\quad W_j^i = w_H^{-i} - \theta_j^i + T^i \qquad \text{if } e_j^i = HE \quad m_j^i = M \\
&\qquad\qquad\quad W_j^i = w_L^i + T^i \qquad\qquad \text{if } e_j^i = LE \quad \forall m_j^i \\
&\quad s.t. \quad cy^j \geq 0 \quad cz^j \geq 0
\end{aligned}
$$

Without loss of generality, we assume that, in the case of indifference, a worker remains in her country of origin. This implies that low-educated individuals will always stay in their home country, i.e. $m_j^i = N \quad \text{if } e_j^i = LE$.

Since households pay for education in their country of origin, regardless of their migration status, government revenue in country i revenue becomes:

$$G^{Ri} = \int_{\mathcal{H}_N^i} \theta_j^i dj + \int_{\mathcal{H}_M^i} \theta_j^i dj = \int_{\mathcal{H}_N^i \bigcup \mathcal{H}_M^i} \theta_j^i dj,$$

where $\mathcal{H}_N^i$ denotes the set of HE workers born in country i that choose to stay home, and $\mathcal{H}_M^i$ is the set of HE workers that choose to work abroad. Formally:

$$\mathcal{H}_N^i = \left\{ j \in [0,1] \mid e_j^i = HE \text{ and } m_j^i = N \right\}$$
$$\mathcal{H}_M^i = \left\{ j \in [0,1] \mid e_j^i = HE \text{ and } m_j^i = M \right\}$$

Thresholds and HE Labor Supply

In the integrated economy, education level and migration status are jointly determined. Because of mobility heterogeneity, there are two cutoffs for each country: one for immobile and one for mobile workers. The first one is determined by the education premium at home, and the second one can be decomposed in a migration premium and an education premium.

For immobile workers, the education decision follows the same rule as in the closed economy. Therefore an immobile worker j from country i becomes HE if her net wage of working in the HE intensive sector of i is higher than the one she would earn in i if she remains LE, i.e., $w_H^i - \theta_j^i \geq w_L$. The threshold for immobile workers in country i is thus given by:

$$\theta_{immobile}^{i*} = w_H^i - w_L \tag{2.13}$$

and every immobile individual j with $\theta_j^i \leq \theta_{immobile}^{i*}$ will choose $e_j^i = HE$.

For intuition, we define $w_H^i - w_L$ as the education premium at home, this is the spread between the wage of a high educated worker and a low educated one. Notice the threshold for immobile workers is given by this premium and every worker that needs to pay a a cost below this value will choose to be high educated and benefit from the spread.

For mobile workers, the education decision must now incorporate the possibility of higher earnings abroad. Hence a mobile worker j in country i decides to become HE if her net wage of working in the HE intensive sector of one of the two countries is higher than the one she would earn in i if she remains LE, i.e., $\max\left\{w_H^i, w_H^{-i}\right\} - \theta_j^i \geq w_L$. The education cost threshold for mobile workers is thus given by:

$$\theta_{mobile}^{i*} = \max\left\{w_H^i, w_H^{-i}\right\} - w_L \tag{2.14}$$

and every mobile individual j with $\theta_j^i \leq \theta_{mobile}^{i*}$ will choose $e_j^i = HE$.

Regarding the migration decision, a HE worker will go wherever she gets a higher wage. This is, $\forall j$ with $e_j^i = HE$:

$$\begin{aligned} m_j^i &= N \quad \text{if } w_H^i \geq w_H^{-i} \\ m_j^i &= M \quad \text{otherwise} \end{aligned}$$

Further manipulation of the threshold for mobile workers (**??**) show that it can be decomposed in a migration and an education premium as follows:

$$\theta_{\text{mobile}}^{i*} = \max\left\{w_H^i, w_H^{-i}\right\} - w_L = \underbrace{\max\left\{w_H^i, w_H^{-i}\right\} - w_H^i}_{\text{Migration Premium}} + \underbrace{w_H^i - w_L}_{\text{Education Premium}}$$

If the migration premium is positive, mobile HE workers benefit from both premia. They earn higher wages because they are high educated and on top of that they get access to even higher wages abroad because they migrate.

Definition 2.4.2 ***Integrated Equilibrium:*** *Given mobility γ and ability distributions $\mathcal{U}[0, \bar{\theta}^i]$, $i \in \{1,2\}$, a competitive equilibrium for the two-country economy is:*

- *education, migration and consumption choices from households: $\left\{e_j^i, m_j^i, cy_j^i, cz_j^i\right\}_{j\in[0,1], i\in\{1,2\}}$,*
- *production plans: $\left\{Y^i, h^i, Z^i, L^i\right\}_{i\in\{1,2\}}$,*
- *lump-sum transfers from the government $\left\{T^i\right\}_{i\in\{1,2\}}$*
- *prices: $\left\{w_H^i, w_L^i\right\}_{i\in\{1,2\}}$, P_Z^w, P_Y^w, and*
- *cutoff education costs: $\left\{\theta_{immobile}^{i*}, \theta_{mobile}^{i*}\right\}_{i\in\{1,2\}}$ such that:*

1. *Given prices, transfers, mobility and ability θ_j^i: $\left\{e_j^i, m_j^i, cy_j^i, cz_j^i\right\}_{i\in\{1,2\}}$ solve j's problem $\forall j$*
2. *Given prices, production plans of IRS sectors $\left\{Y^i, h^i\right\}_{i\in\{1,2\}}$ satisfy $w_H^i = A(H^i) \cdot P_Y^w$*

3. *Given prices, production plans of CRS sectors* $\left\{Z^i, L^i\right\}_{i\in\{1,2\}}$ *satisfy* $w_L = B \cdot P_Z^w$

4. *Government budget balances in each country* $(i = 1, 2)$*:*

$$\int_{\mathcal{H}_N^i \bigcup \mathcal{H}_M^i} \theta_j^i dj = \int_0^1 T^i dj$$

5. *Labor markets clear (in each* $i = 1, 2$*):*

$$\begin{aligned} H^{si} &\equiv \int_{\mathcal{H}^i} j dj \\ h^i &= H^i \qquad\qquad H^i = H_N^i + H_M^{-i} \\ L^i &= L_N^i + L_M^{-i} \\ 1 &= H_N^i + H_M^i + L_N^i \qquad wlog \quad L_M^{-i} = 0 \end{aligned}$$

6. *Good markets clear:*

$$\begin{aligned} Y^1 + Y^2 &= \int_{\mathcal{H}^1} c_Y^H dj + \int_{\mathcal{H}^2} c_Y^H dj + \int_{\mathcal{L}^1} c_Y^L dj + \int_{\mathcal{L}^2} c_Y^L dj \\ Z^1 + Z^2 &= \int_{\mathcal{H}^1} c_Z^H dj + \int_{\mathcal{H}^2} c_Z^H dj + \int_{\mathcal{L}^1} c_Z^L dj + \int_{\mathcal{L}^2} c_Z^L dj \end{aligned}$$

Where $\mathcal{H}^i = \mathcal{H}_N^i \bigcup \mathcal{H}_M^i$ *and* $\mathcal{L}^i = \left(\mathcal{H}_N^i \bigcup \mathcal{H}_M^i\right)^c$.

Characterization of the Integrated Equilibrium

For households, optimal consumption choices are as in the closed economy. However, the introduction of migration choice generates two equilibrium objects in the HE sector: (i) Aggregate supply of native HE labor H_N^i and (ii) Aggregate supply HE emigrants H_M^i. Each one is determined in equilibrium according to individual-specific mobility and ability draw, following the cutoff rules described above. These thresholds are determined by the relative price of final goods, which, at the same time, depend on the aggregate stock of HE workers.

Individual supply of HE immobile labor is given by

$$e_j^i = HE \text{ if } w_H^i - \theta_j^i \geq w_L$$

Using the distribution of θ_j^i and the share of immobile workers $1-\gamma$, we get an expression for the aggregate supply of immobile HE native workers:

$$H_{N,immobile}^i = \left(\frac{w_H^i - w_L^i}{\bar{\theta}^i}\right) \cdot (1 - \gamma) \tag{2.15}$$

Individual supply of HE mobile labor is given by:

$$e_j^i = HE \text{ if } \max\left\{w_H^i, w_H^{-i}\right\} - \theta_j^i \geq w_L$$

Using the distribution of θ_j^i and the share of mobile workers γ, we get an expression for the aggregate supply of mobile HE natives and emigrants:

$$H_{N,mobile}^i = \left(\frac{w_H^i - w_L^i}{\bar{\theta}^i}\right) \cdot \gamma \qquad H_M^i = 0 \qquad \text{if } w_H^i \geq w_H^{-i} \tag{2.16}$$

$$H_{N,mobile}^i = 0 \qquad H_M^i = \left(\frac{w_H^i - w_L^i}{\bar{\theta}^i}\right) \cdot \gamma \qquad \text{otherwise,} \tag{2.17}$$

where

$$\begin{aligned}
H^i &= H_N^i - H_M^i + H_M^{-i}, \quad H_N^i = H_{N,mobile}^i + H_{N,immobile}^i \\
w_H^i &= A(H^i) \\
w_L^i &= BPz \\
Pz &= \frac{(1-\lambda)\left(A(H^i) \cdot H^i + A(H^{-i}) \cdot H^{-i}\right)}{\lambda(2 - H^i - H^{-i})}
\end{aligned}$$

This completes the characterization of equilibria for the general case. In the next section, we provide a discussion of specific cases.

2.5 Results and Discussion

We are interested on the comparison of countries with different distribution of native HE population. In particular we want model two countries, one with a higher fraction of native HE workers to show it will attract HE immigrants, in line with our empirical analysis. In our model we generate a heterogeneity on HE native shares by considering different abilities distribution, which in turns translates into different education costs.

Assumption 2.5.1 *Maximum education cost in country 1 is lower than in country 2, i.e.* $\bar{\theta}_1 < \bar{\theta}_2$.

Assumption 2.5 implies that, in autarky, both the share of HE workers and their wage are higher in country 1 than in country 2 [10].

[10] See Figure 2.2.

Since the sector that uses HE labor as input exhibits external economies of scale, we expect that, by opening the borders and allowing for labor mobility, foreign HE workers will flow to country 1. This will be analyzed in *Case 1*.

We acknowledge that in our model, as in other models with external economies of scale, there is a multiplicity of equilibria. For our analysis, this means that, even if country 1 has a higher labor and wage in the HE intensive sector in autarky, it is possible for HE labor to cluster in country 2. For this equilibrium to arise, people would need to expect higher wages in country 2 even though they are lower in autarky. For completeness, we will briefly discuss this equilibrium in *Case 2*[11]

For *Case 1* we conjecture and impose[12] that $w_H^{1w} > w_H^{2w}$.

As a result, every mobile household from 2 will migrate to country 1, whereas every mobile household from country 1 will stay there. Figure 2.3 illustrates this equilibrium and contrasts it to the equilibrium in autarky. For the open case, we set the ratio $\bar{\theta}^2/\bar{\theta}^1$ to 1.5 and the mobile fraction γ to 0.5 [13]. In particular we use $\bar{\theta}_1 = 2$ and $\bar{\theta}_2 = 3$ to account for the differences in ability. Table **??** contains the numerical results, and Figure 2.3 provides an illustration. In autarky, 22% of the total population in country 1 is HE, in contrast to 11% in country 2. When workers are allowed to move freely, these numbers change to 39% and 1%, respectively. This is, 39% of the residents of country 1 are employed by the IRS sector, while only 1% of the residents of country 2 are HE.

[11] We plan to extend the analysis of this Case by introducing beliefs in the model. However at this stage of the paper, we have not modeled them modeled beliefs explicitly, this is an additional reason for why we will only comment briefly on *Case 2*.

[12] After this conjecture we verify with the numerical results, following a guess and verify approach.

[13] The rest of the parameters are the same as in Figure 1 of the closed economy

Figure 2.3: Specialization Patterns: Case 1

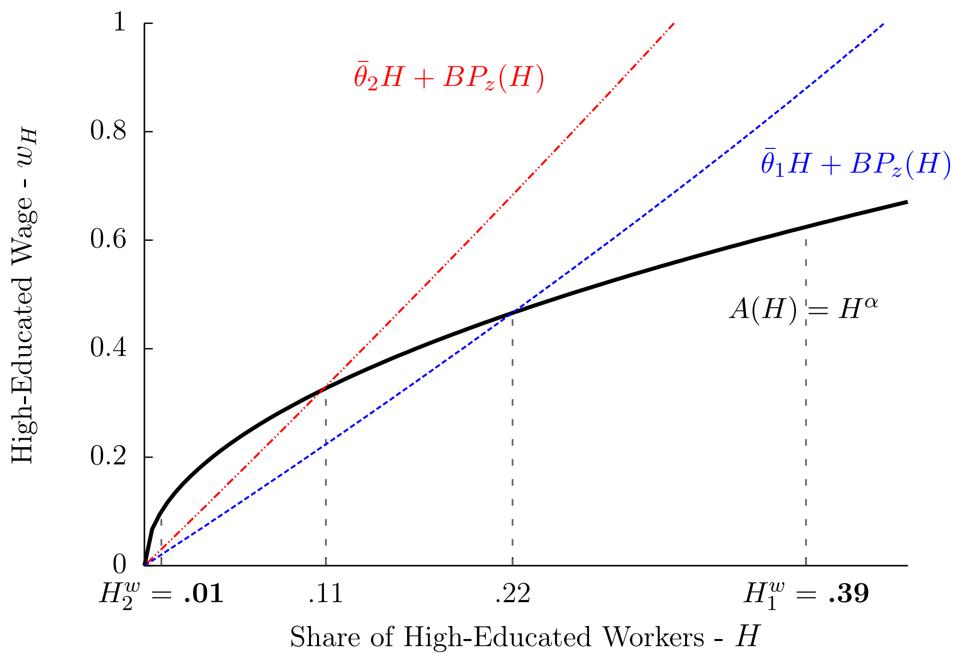


Table III: Numerical Results

	Autarky		**Integrated**	
	Country 1	Country 2	Country 1	Country 2
Residents	1	1	$1 + H_M^2$	$1 - H_M^2$
HE	21.66	10.47	39.14	1.13
LE	78.34	89.53	70.64	89.08

-

The relation between HE immigrants and HE natives in country 1 is given by:

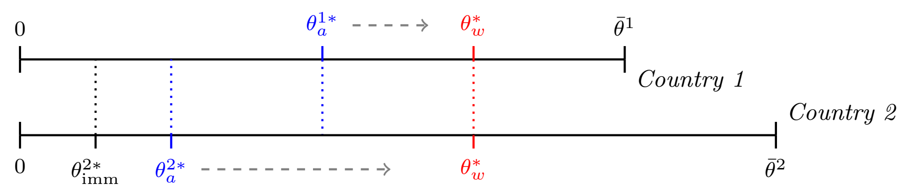
$$\frac{H_M^2}{H_N^1} = \frac{\bar{\theta}_1}{\bar{\theta}_2}\gamma \tag{2.18}$$

Equation 2.18 establishes a linear relation between HE natives and immigrants. Given a stock of H_N^1, the share of workers who migrate from country 2 to 1 is determined by two factors, depending only on parameters of the model. The first one is trivial: immigration increases with mobility (higher γ). The second factor is the relative difference in education costs: the higher the education costs in country 2 with respect to country 1, the lower the share of immigrants for a given number of HE natives. For a constant level of $\bar{\theta}_1$, increases in $\bar{\theta}_2$ discourage workers from country 2 from becomming HE since the cost they have to pay at home does not compensate for the higher wages abroad.

As *Case 1* and Figure 2.3 illustrate, the main result of our model is that if a country has a relatively larger fraction of native population working in the high educated (IRS) sector, this country will attract foreign labor of the same type. This is consistent with "north-north" migration patterns observed in HE occupations our sample of analysis. The model we propose in this paper allows for the possibility of workers migrating to a place where there are more of their type, as opposed to the standard south-north approach where migration flows are due to scarcity: workers migrating to places where there are less of their type.

Additionally we find that in a human capital free mobility are with free mobility of labor and transferability of education, the interaction between migration and education decisions increase the total HE labor stock. Other workers decide to become HE to take advantage of migration premium and spillovers from the IRS sector. This translates into agents willing to pay higher education costs (see Figure 2.4).

Figure 2.4: Thresholds



In our numerical exercise, the threshold for becoming HE increases for both countries under the integrated economy. In the host country HE wages increase with the inflow of HE immigrants due to the production externality and therefore more people become HE. In the source country mobile workers are willing to pay more for their education since they can benefit from higher wages abroad.

In *Case 2*, even though we begin with $w_H^{1a} > w_H^{2a}$, we conjecture and impose $w_H^{1w} < w_H^{2w}$.

As a result, there is agglomeration of HE labor in country 2 [14]. Despite the fact that this case is possible, it is not desirable because it induces a lower level of world GDP, consumption and welfares (see Table IV).

Table IV: Sectoral Output, World GDP and Welfare

	Output			Welfare		
	$Y_1 + Y_2$	$Z_1 + Z_2$	Total GDP	Cou.1	Cou.2	Total
Case 1	0.25	1.60	0.31	-1.60	-2.39	-3.99
Case 2	0.18	1.64	0.23	-2.25	-2.14	-4.40

-

2.6 Conclusion

In this paper, we have first provided evidence that, if a EU15 country has a relatively larger fraction of native population working in a high-educated occupation, this country will attract foreign EU15 labor of the same type. This result is in line with what we have refer to as north-north migration pattern, where workers migrate to countries similar to their source country and where their type is relatively more abundant. We have also documented that high-educated occupations display concentration patterns in the sense that workers in those occupations tend to cluster in specific countries.

As we have emphasized, the intra EU15 migration phenomenon cannot be studied under the traditional south-north approach. The reason is that this framework assumes differences between the source and the host countries in terms of both income and characteristics of their labor force that are not observed in the EU15. To fill this gap, in this paper we propose a model that allows for workers flows between similar countries. Moreover, our model successfully generates the EU15 migration patterns we have documented and it also rationalizes agglomeration consistent with the concentration findings we have documented.

The mechanism of our model is the following: wages for HE labor are strictly increasing in the amount of HE labor, both foreign and native, employed in a country. This is achieved via external economies of scale in the sector intensive in HE labor. Hence, at the individual

[14] See the system of equations that determines the equilibria and the figure in appendix.

level, it becomes worthy for the most able households to become HE and to move to the country where there are more HE native workers.

To properly analyze selective policies of migration, it is imperative to propose better mechanisms of analysis that allow for bilateral flows of workers from economically similar countries. The theoretical framework developed in this paper provides useful insight about how to model a mechanism capable of driving migration and generating agglomeration.

Our model can be extended along several dimensions. For instance, we used the convenient relation between the ISCO-88 occupation classification and the education level to relate our model to the data. However, we acknowledge that reducing the types of workers to be based only on education limits the applications of our model. In this sense, allowing for occupational differences might be insightful. We think important differences arise in terms of transferability of skills and mobility between occupations, regardless of their education level. Additionally we could allow for migration in the CRS sector.

Another interesting direction is to include more structure in the CRS sector. In particular we could include a sector in the model that displays CRS or even decreasing returns to scale, and that is attached to the size or structure of the population in each country. This could be interesting since there are differences within the low-educated (LE) group in the data. Service Elementary occupations workers behave very differently from, for example, Machine Operators[15]. This could happen because the former group faces a considerably inelastic demand and is directly attached to the population size. In contrast, the latter group is more exposed to country-specific sectoral shocks. For instance, we think of the 2000's construction boom in Spain as an exogenous increase in Spain's construction labor productivity, B^i, that can drive a positive correlation between the share of native and immigrants.

[15]Groups 91 and 81 at the 2-digit ISCO-88 level, respectively.

Chapter 3

Macroeconomic Effects of Medicare

3.1 Introduction

Medicare is one of the largest health insurance programs in the world. In 2015 it provided health insurance to about 52 million Americans and comprised 17.3 percent of federal outlays, or 3.6 percent of GDP. This paper aims to improve our understanding of the role of Medicare in the macroeconomy. To do this, we develop a general equilibrium overlapping generations model with incomplete markets and heterogeneous consumers. In the model, consumers differ along the dimensions of age, education, health status, labor productivity, assets, and health insurance status. The consumers are subject to idiosyncratic uncertainty on their labor productivity and health, the latter of which determines their medical expenses. While shocks to labor productivity are uninsurable, medical expenses are partially insurable in the form of Medicare, Medicaid, private, and employer-provided health insurance. We use the model to calculate the effects of an unexpected elimination of Medicare. This numerical experiment enables us to capture the effects of Medicare on macroeconomic aggregates, insurance enrollment, government spending, and welfare.

We start by comparing the steady state of the economy with and without Medicare. Eliminating Medicare leads to a 2.7 percentage point reduction in payroll taxes and a 1.3 percent increase in wages. Wages increase because capital increase as consumers raise their saving to finance the higher cost of medical expenses in old age. The combination of higher wages and lower payroll taxes raises labor supply and generates an increase in output per capita of 2.0 percent.

We then compare the insurance distribution in the two economies. Our results show that a large share of the elderly respond by substituting Medicaid for Medicare. This increases spending on Medicaid from 3.6 to 5.3 percent of GDP. Spending on Social Security benefits also increases from 4.7 to 4.8 percent of GDP because wages surge following the rise in capital. As a result, government spending as a share of GDP only declines by 1.5 percentage points following the elimination of Medicare. We thus find that the government saves only 46 cents for every dollar it cuts on Medicare due to offsetting spending on Medicaid and Social Security.

Next, we examine the ex-ante welfare effects of the reform on unborn consumers under the veil of ignorance. We find that ex-ante welfare is higher in the steady state without Medicare. In particular, we find that consumption has to increase by 3.6 percent in all periods and contingencies in the economy with Medicare to make an unborn consumer under the veil of ignorance indifferent between the two steady states. This follows from the observation that the reform leads to lower taxes and higher wages, both of which facilitate higher consumption and saving.

We then examine the ex-post welfare effects of the reform on the current cohorts. To do this, we first solve for the transition path between the economy with and without Medicare. This enables us to account for the costs of transiting between the steady states. In particular, it enables us to account for the costs of accumulating assets to finance the higher cost of medical expenses in old age.

We start by examining the ex-post welfare effects on consumers in different age brackets. Our estimates show that the majority of the young would benefit from the policy change due to the reform's effect on payroll taxes and wages. The majority of the elderly, on the other hand, are better off in the economy with Medicare. After summing across all age brackets, we find that 56.8 percent of the population alive in the period of the reform would benefit from the elimination of the program.

Next, we quantify the ex-post welfare effects on those that benefit and lose from the reform by computing the dollar value of how much wealth must change in the initial steady state to make the consumers weakly better off in the economy with Medicare than in the transition to the economy without Medicare. We find that those that benefit from the reform experience an average welfare gain that is equivalent to receiving $\$3,600$ higher wealth in the steady state with Medicare. In contrast, those that lose from the reform experience an average welfare loss that is equivalent to at least a $\$27,700$ reduction in wealth. As a result, we find that the elimination of Medicare lowers aggregate welfare, and that the per capita welfare loss of the reform is equivalent to at least a $\$9,900$ reduction in wealth in the initial steady state. Note that this is a lower bound for the welfare loss of the reform. This follows from the fact that consumers are not allowed to borrow in our model. Consequently, some consumers will be strictly better off in the economy with Medicare even if they forfeit all of their current wealth. In this case, we find that the constraint binds for 9.4 percent of the population.

Lastly, we consider an additional ex-post welfare measure that quantifies the welfare effect by computing the average consumption equivalent variation across consumers. We show that our finding that aggregate welfare declines following the elimination of Medicare is robust to using this alternative welfare measure.

The paper is organized as follows. The next section relates our contribution to the literature. In section 3 we lay out the environment of our economy and set up a quantitative life cycle model. This section also presents the different types of health insurance that are available in the economy. After calibrating the model in section 4, we turn to the policy experiments. Section 5 starts by studying the macroeconomic effects of eliminating Medicare. The section also considers an alternative reform where we eliminate both Medicare and

Medicaid. Section 6 discusses the robustness of our results to alternative parameterizations of the model. Lastly, section 7 concludes and gives directions for future research.

3.2 Relation to the literature

This paper is related to several strands of the literature. Our framework is similar to the one Conesa and Krueger (1999) use to study the aggregate effects of Social Security reforms. Their model has two essential features for our analysis. First, it takes a life cycle perspective on consumption, assets, and labor decisions. Second, it accounts for general equilibrium feedback effects. We extend their model by incorporating idiosyncratic risk to health and by allowing consumers to enroll in private and public health insurance programs.

We build on the literature that uses overlapping generations models to study the macroeconomic effects of health and aging. Attanasio et al. (2010) study the implications of an aging population for the financing of Medicare, but they do not explicitly model Medicaid, a program that we show is essential to determine consumers' saving and insurance behavior upon changes to Medicare. Pashchenko and Porapakkarm (2013) study the welfare effects of the Patient Protection and Affordable Care Act (ACA). Our model is closely related to theirs, except that we endogenize the retirement decision, since 20 percent of the population aged 65 and older are still active in the labor market. Jung and Tran (2016) use a model with endogenous health to quantify the effects of ACA. They do not, however, study transitional dynamics. Conesa and Krueger (1999) and Krueger and Ludwig (2016) argue that a full characterization of the transition path is crucial for policy evaluation. Comparative statics exercises fail to account for potentially large transitional costs, and hence give at best a partial picture of the effects of policy reforms. Bairoliya et al. (2017) and İmrohoroğlu and Zhao (2017) develop overlapping generations models to study health insurance and social security reforms in China. McGrattan and Prescott (2017) propose an overlapping generations model to study the impacts of fiscal policies in economies that are undergoing a demographic change. Lastly, Borella et al. (2017) examine the importance of including gender and marriage in structural life cycle models.

We also contribute to the literature on precautionary saving and its interaction with medical expenditure shocks. Hubbard et al. (1994) and Palumbo (1999) study the role of out-of-pocket medical expenditure risk in life cycle models. De Nardi et al. (2010) find that accounting for medical expense risk is important in explaining the observed saving of the elderly.

Lastly, our paper is related to the empirical literature studying social insurance programs. Finkelstein (2007) and Finkelstein and McKnight (2008) estimate the impact of Medicare on insurance coverage, health care utilization, and spending. They find that the introduction of Medicare increased the share of elderly with insurance coverage by 75 percentage points and led to a significant reduction in the elderly's exposure to out-of-pocket medical expenditure risk. Finally, Michaud et al. (2017) examine the impact of demographic changes on Social Security Disability Insurance trends.

3.3 Model

The following subsections present the benchmark model used in the analysis. The model is a discrete time, general equilibrium, overlapping generations model with ex-ante heterogeneous consumers, where consumers differ in age, educational level, health status, labor productivity, assets, and health insurance status.

3.3.1 Consumers

The economy is populated by a continuum of ex-ante consumers. Consumers are indexed by type $s = (j, e, h, \eta, a, i)$, where j denotes age, e is educational level, h denotes health status, η is labor productivity, a denotes assets, and i is the consumer's health insurance status. Throughout we let $\Phi(s)$ denote the measure of consumers of type s.

The consumer's educational level can take on one of two values: college or non-college. For simplicity, we assume that the consumer's educational level is permanent over her lifetime. Health status is stochastic and depends on the consumer's current age, education, and health. It follows a finite-state Markov process with stationary transitions over time:

$$Q_{j,e}(h, H) = Prob\left(h' \in H \,:\, (h,\, j,\, e)\right). \tag{3.1}$$

Labor productivity is given by a stationary finite-state Markov process:

$$Q(\eta, E) = Prob\left(\eta' \in E \,:\, \eta\right). \tag{3.2}$$

Lastly, the consumer's health insurance status specifies if she is self-insured or has private health insurance, employer-provided health insurance, or health insurance provided by the government in the form of Medicare. Health insurance is used to cover medical expenses, m_{jh}, which vary with the consumer's age and health status.

Consumers are endowed with one unit of time in every period that can be allocated to work and leisure. We assume that consumers can work in old age. This assumption is motivated by the observation that nearly 20 percent of individuals aged 65 and older still participate in the workforce. Labor supply, ℓ, is indivisible and can take on one of four values: $\ell \in \{0, \ell_p, \ell_f, \ell_e\}$, where p, f, and e refer to part time, full time, and extra time, respectively. In addition to leisure, consumers also derive utility from consumption, c. The period-by-period return function is given by

$$U(c, \ell) = \frac{\left[c^{\gamma}(1-\ell)^{1-\gamma}\right]^{1-\sigma}}{1-\sigma}. \tag{3.3}$$

Starting at age j_r, all consumers receive health insurance from the government in the form of Medicare. They also receive Social Security benefits SS_e that depend on their education. Lastly, consumers face a survival probability ψ_{jeh} that depends on their age, education, and health. All consumers that survive until age J die with probability one. In the event of death, the consumer's assets are uniformly distributed across the population by means of lump-sum transfers, B.

3.3.2 Health insurance and government welfare programs

This section presents the different types of health insurance that are available in the economy. As noted earlier, health insurance is available in the form of private insurance, employer-provided insurance, and Medicare. Health insurance is also provided by the government in the form of Medicaid and a combination of food stamps and basic medical relief (for brevity, referred to as food stamps below). The consumer's insurance status determines what fraction of her medical expenses must be paid out-of-pocket, m_{op}. Throughout, we let χ_P, χ_E, χ_{CARE}, and χ_{CAID} denote the copayment parameter for private health insurance, employer-provided health insurance, Medicare, and Medicaid, respectively.

Private health insurance

Consumers can purchase health insurance for the following period from private insurance companies. We let private insurance companies price-discriminate based on age, education, and health. We assume that the price is actuarially fair for each insurance pool (j, e, h). That is, the firm breaks even on each insurance pool. This gives the following expression for the insurance premium:

$$\pi_{jeh} = \begin{cases} \frac{\psi_{jeh}(1-\chi_P)\int m_{j'h'} Q_{j,e}(h, dh')}{(1+r')} & \text{if } j < j_r - 1 \\ \\ \frac{\psi_{jeh}(1-\chi_P)\chi_{CARE}\int m_{j'h'} Q_{j,e}(h, dh')}{(1+r')} & \text{if } j \geq j_r - 1. \end{cases} \tag{3.4}$$

We assume that Medicare is the primary payer for all elderly consumers. That is, in the event that a consumer is covered by both Medicare and private insurance, Medicare pays first.

Employer-provided health insurance

We assume that a fraction of workers have health insurance provided by their employer. The employer pools the medical expenses of all their employees that do not choose to go on food stamps. These costs are then split evenly between all employees that currently work positive hours. That is, we model employer-provided health insurance as a pay-as-you-go system where current contributors pay for the health expenditures of current receivers. The premium is thus given by

$$\bar{\pi}_E = \frac{(1-\chi_E)\int \mathbb{I}_{F=0} m_{jh} \Phi\left(\{1,\ldots,j_r-1\} \times de \times dh \times d\eta \times da \times \left\{i^E\right\}\right)}{\int \mathbb{I}_{\ell>0} \Phi\left(\{1,\ldots,j_r-1\} \times de \times dh \times d\eta \times da \times \{i^E\}\right)}, \tag{3.5}$$

where the indicator function $\mathbb{I}_{F=0}$ in the numerator equals one for all consumers that do not choose to go on food stamps. We assume that consumers cannot have both employer-provided and private health insurance, and that consumers cannot opt out of employer-provided insurance. The latter assumption is needed to alleviate the adverse selection problem associated with group insurance plans, which would arise in our model due to our abstracting from tax deductions for employer-provided health insurance premia. Jeske and Kitao (2009) find that these deductions discourage healthy individuals to opt out of group insurance in favor of private insurance. Lastly, we assume that consumers aged j_r and older are not eligible for employer-provided health insurance. This is motivated by data from the Medical Expenditure Panel Survey which show that the percentage of individuals with employer-provided insurance drops from about 50 to 20 percent between the ages of 60 and 70. Since consumers aged j_r and older are not eligible for employer-provided health insurance, we let consumers of age $j_r - 1$ with employer-provided insurance purchase private insurance for the following period.

Medicaid

Medicaid is a means-tested program that provides health insurance to the poor. There are two ways to qualify for Medicaid. First, consumers are eligible for Medicaid if the sum of their gross income and interest earnings is below a threshold y^{cat}. Second, consumers also qualify for Medicaid if the sum of their gross income and interest earnings net of out-of-pocket medical expenses is below a threshold y^{mn} and their assets are less than a^{mn}. Following Pashchenko and Porapakkarm (2013), we call the two eligibility criteria “categorical eligibility” and “eligibility based on medical need,” respectively.

Medicare

The government also provides health insurance in the form of Medicare. Unlike Medicaid, Medicare is not a means-tested program, but provides equal health insurance to all the elderly. Since Medicare does not cover all out-of-pocket medical expenses, elderly consumers can purchase private insurance as a complementary insurance.

Food stamps and basic medical relief

Finally, the government provides health insurance in the form of a combined food stamps and basic medical relief program. The program combines institutional features of food stamps, disability insurance, and basic medical relief for the poor. To qualify for this program in the model, consumers have to forfeit all assets and work zero hours. In return, the government pays for all out-of-pocket medical expenses and guarantees a minimum consumption level, $\underline{c}$.

3.3.3 Consumer problem

The consumer's choice set depends on her current age and insurance status. Throughout, we use the word *young* to denote consumers less than age j_r and *old* to denote consumers that are at least j_r years old. We start by presenting the problem of a young consumer without employer-provided health insurance. This subsection also defines the value of going on food stamps. Next, we set up the problem faced by young consumers with employer-provided health insurance. Lastly, we discuss the problem of old consumers.

Young consumers without employer-provided health insurance

Recall that a consumer's type is given by $s = (j, e, h, \eta, a, i)$, where j denotes age, e is educational level, h denotes health status, η is labor productivity, a denotes assets, and i is the consumer's health insurance status. Let $V^I(s)$ denote the value of young consumers without employer-provided health insurance. Similarly, let $V^F(s)$ denote the value of food stamps. Consumers without employer insurance that do not choose to go on food stamps may or may not purchase private insurance for the following period. This yields the following problem:

$$V(s) = \max \left\{ V^I(s), V^F(s) \right\}, \tag{3.6}$$

where $V^I(s)$ is given by

$$
\begin{aligned}
V^I(s) \quad &= \quad \max_{c,a',\ell,i'} \; U(c,\ell) + \beta\psi_{jeh} \iint V(s') Q(\eta, d\eta') Q_{j,e}(h, dh') \\
& \qquad s.t. \quad c + a' + m_{op} + \mathbb{I}_{i'=i_P}\pi_{jeh} = w(1-\tau)\epsilon_{je}\eta\xi(h)\ell \\
& \qquad\qquad\qquad + (1+r)(a+B) + \mathbb{I}_{Med}(s,\ell)(1-\chi_{CAID}) m_{op} \\
& \qquad\qquad m_{op} = \mathbb{I}_{i=i_P}\chi_P m_{jh} + (1-\mathbb{I}_{i=i_P}) m_{jh} \\
& \qquad\qquad \ell \in \{0, \ell_p, \ell_f, \ell_e\} \\
& \qquad\qquad c, a' \geq 0 \\
& \qquad\qquad i' \in \{i_P, i_S\}.
\end{aligned}
\tag{3.7}
$$

Here, $i = i_P$ means the consumer has private health insurance, and $i = i_S$ means the consumer is self-insured. The indicator function, $\mathbb{I}_{Med}(s,\ell)$, equals one if the consumer qualifies for Medicaid. Medicaid covers a share $1-\chi_{CAID}$ of out-of-pocket medical expenses, which are given by m_{jh} for self-insured consumers and $\chi_P m_{jh}$ for consumers that purchased private insurance in the preceding period. Lastly, labor earnings depend on the consumer's stochastic labor productivity, η, health, $\xi(h)$, and deterministic life cycle productivity, ϵ_{je}, the last of which varies with age and education.

To qualify for food stamps in the model, consumers have to forfeit all assets and work zero hours. In return, the government covers all out-of-pocket medical expenses and provides the consumer with consumption $\underline{c}$. The value of food stamps is thus given by

$$
\begin{aligned}
V^F(s) \quad &= \quad U(\underline{c}, 0) + \beta\psi_{jeh} \iint V(s') Q(\eta, d\eta') Q_{j,e}(h, dh') \\
& \qquad s.t. \quad a' = 0 \\
& \qquad\qquad\quad i' = i_S.
\end{aligned}
\tag{3.8}
$$

Young consumers with employer-provided health insurance

Let $V^E(s)$ denote the value of being on employer-provided health insurance. Consumers with employer insurance choose whether or not to go on food stamps. This yields the following problem:

$$V(s) = \max \; \left\{V^E(s), V^F(s)\right\}, \tag{3.9}$$

where $V^E(s)$ is given by

$$\begin{aligned}
V^{E}(s) &= \max_{c,a',\ell} U(c,\ell) + \beta\psi_{jeh} \iint V(s')Q(\eta, d\eta')\, Q_{j,e}(h, dh') \\
s.t.\quad & c + a' + m_{op} + \mathbb{I}_{\ell>0}\bar{\pi}_E = w(1-\tau)\,\epsilon_{je}\eta\xi(h)\,\ell \\
&\qquad + (1+r)(a+B) + \mathbb{I}_{Med}(s,\ell)(1-\chi_{CAID})\, m_{op} \\
& m_{op} = \chi_E m_{jh} \\
& \ell \in \begin{cases} 0, \ell_p, \ell_f, \ell_e & \text{if sick} \\ \ell_p, \ell_f, \ell_e & \text{if healthy} \end{cases} \\
& c, a' \geq 0 \\
& i' = i_E.
\end{aligned} \tag{3.10}$$

Out-of-pocket medical expenses are given by $\chi_E m_{jh}$ for consumers on employer insurance. All consumers on employer insurance that work positive hours must pay a premium $\bar{\pi}_E$. We assume that healthy consumers on employer insurance have to supply a minimum of $\ell_p > 0$ hours. Sick consumers, on the other hand, are free to choose zero hours. In the model, consumers are considered sick if they have a catastrophic health state. Finally, the value of going on food stamps is the same as above, with the exception that consumers continue to be eligible for employer-provided insurance in the following period, $i' = i_E$.

Old consumers

Let $V^R(s)$ denote the value of an old consumer of type s. Similarly to young consumers without employer-provided health insurance, old consumers that do not choose to go on food stamps may or may not purchase private insurance for the following period. This yields the following problem:

$$V(s) = \max \ \left\{V^R(s), V^F(s)\right\}, \tag{3.11}$$

where $V^R(s)$ is given by

$$\begin{aligned} V^R(s) \quad = \quad & \max_{c,a',\ell,i'} U(c,\ell) + \beta\psi_{jeh} \iint V(s') Q(\eta, d\eta') Q_{j,e}(h, dh') \\ s.t. \quad & c + a' + m_{op} + \mathbb{I}_{i'=i_P}\pi_{jeh} = w(1-\tau)\epsilon_{je}\eta\xi(h)\ell \\ & \qquad + (1+r)(a+B) + SS_e + \mathbb{I}_{Med}(s,\ell)(1-\chi_{CAID}) m_{op} \\ & m_{op} = \mathbb{I}_{i=i_P}\chi_P\chi_{CARE} m_{jh} + (1-\mathbb{I}_{i=i_P})\chi_{CARE} m_{jh} \\ & \ell \in \{0, \ell_p, \ell_f, \ell_e\} \\ & c, a' \geq 0 \\ & i' \in \{i_P, i_S\}. \end{aligned} \tag{3.12}$$

All consumers start receiving Medicare and Social Security benefits at age jr. Neither program is tied to retirement, and hence consumers continue to receive both Medicare and Social Security benefits even if they choose to work in old age. Out-of-pocket medical expenses are given by $\chi_{CARE}m_{jh}$ for self-insured consumers and $\chi_{CARE}\chi_P m_{jh}$ for consumers that purchased private insurance in the preceding period.

3.3.4 Firms

Firms hire labor at wage w and rent capital at rate r from the consumers to maximize profits. We assume that the aggregate technology can be represented by a constant returns to scale Cobb-Douglas production function:

$$Y = \theta K^{\alpha} N^{1-\alpha}, \tag{3.13}$$

where θ denotes total factor productivity, K is the aggregate capital stock, N denotes aggregate labor supply (measured in efficiency units), and α is capital's share of income. Output is used for consumption, C, investment, $I = K' - (1-\delta)K$, and to cover medical expenses, M:

$$C + M + K' = \theta K^{\alpha} N^{1-\alpha} + (1-\delta)K, \tag{3.14}$$

where δ is the rate of depreciation.

3.3.5 Government

Let b_e denote the Social Security replacement rate conditional on the consumer's educational level. Social Security benefits SS_e then satisfy

$$SS_e = \frac{b_e w N}{\int \Phi\left(\{1, \ldots, j_r - 1\} \times de \times dh \times d\eta \times da \times di\right)}. \tag{3.15}$$

The government finances its costs of providing health insurance, food stamps, and Social Security by means of payroll taxes. For simplicity, we assume that the government balances its budget period-by-period. Let *gov* denote the total government expenditure on health insurance and food stamps. Taxes on labor income, τ, then have to satisfy

$$\tau w N = SS_e \int \Phi\left(\{j_r, \ldots, J\} \times de \times dh \times d\eta \times da \times di\right) + gov. \tag{3.16}$$

3.3.6 Definition of equilibrium

Given a replacement rate b_e, copayment parameters χ_P, χ_E, χ_{CARE}, and χ_{CAID}, and initial conditions for capital K_1 and the measure of types Φ_1, an *equilibrium* in our model is a sequence of model variables such that:

1. Given prices, insurance premia, government policies, and accidental bequests, consumers maximize utility subject to their constraints.

2. Factor prices satisfy marginal product pricing conditions.

3. Government policies satisfy the government budget constraint.

4. Goods, factor, and insurance market clearing conditions are met.

5. Aggregate law of motion for Φ is induced by the policy functions and the exogenous stochastic processes for idiosyncratic risk.

3.4 Calibration

This section describes how we map the model to the data. We start by presenting the health expenditure data used in this paper. Next, we discuss how we compute the health insurance copayment parameters, how the Medicaid eligibility criteria are determined, and how we compute the health transition probabilities. The last two subsections summarize the calibration of the preference and technology parameters, and the parameters of the idiosyncratic earnings process.

3.4.1 Health expenditure

We use data from the Medical Expenditure Panel Survey (MEPS). The MEPS collects detailed records on medical expenditure, insurance, income, and demographics for a nationally representative sample of households. The survey consists of two-year overlapping panels for the period 1996 to 2013, of which we use data from 1996 to 2010 for individuals aged 20 to 85 years. All current price series are converted to 2010 dollars using the GDP deflator.

We split medical expenses into three categories: low, high, and catastrophic. To identify these expenses in the data, we first pool all medical expenses for each age group and compute the 60th and 99.9th percentile. We then identify low, high, and catastrophic expenses as the average value between the 0-60th percentile, the 60-99.9th percentile, and the 99.9-100th percentile. Next, we assume a logarithmic trend. Since the MEPS pools all medical expenses for individuals older than 85, we extrapolate medical expenses for consumers aged 85 to 100. Lastly, we scale the expenditures to match the 16.5 percent health expenditures-to-GDP ratio observed in the United States between 2006 and 2010. These series are illustrated in figure 1. We also report how medical expense risk varies over the life cycle. This is illustrated in figure 2, which shows that both the mean and variance of medical expenses increase as people age.

3.4.2 Health insurance parameters and Medicaid eligibility criteria

To compute the copayment parameter on private insurance, employer insurance, and Medicaid, we first derive each consumer's primary insurance provider, defined as the insurer that pays for most of the consumer's expenses. For instance, if Medicaid covers most of the consumer's expenses, but she also pays some expenses out-of-pocket, Medicaid will be her primary insurance provider. We then compute the average share of expenses paid by Medicaid across consumers with Medicaid as their primary insurance provider, and let the copayment parameter on Medicaid be given by the complement of this share. The same method is used to compute the copayment parameter on private insurance and employer insurance. Given data from the MEPS, we obtain a copayment parameter on private insurance and employer insurance of 22.9 percent, and a copayment parameter on Medicaid of 13.8 percent. We use the same copayment parameter on private and employer insurance since the MEPS pools expenses covered by these insurance plans.

Recall that all of the elderly receive Medicare in the model and that Medicare is their primary payer (that is, in the event that an old consumer is covered by multiple insurance plans, Medicare pays first). An implication of this assumption is that the percentage of the elderly's total health expenses that is paid by Medicare will always be equal to the complement of the Medicare copayment parameter in the model. In other words, using a

Medicare copayment parameter of x percent means that Medicare will pay for $1-x$ percent of the elderly's total medical expenses. Data from the MEPS show that Medicare pays for 46.9 percent of the elderly's total health expenses and for 70.9 percent of the medical expenses of those with Medicare as their primary insurance provider. To better match the age-specific insurance distribution in the data, we pick a value closer to the first estimate and let the copayment parameter on Medicare be 50.0 percent.

Prior to ACA, financial eligibility criteria for Medicaid varied considerably across states, but were typically well below the federal poverty level (FPL). Data from the Kaiser Family Foundation show that 33 states had a categorical income limit below the FPL in 2009, which was about $\$10,800$, or 23 percent of GDP per capita. The weighted average categorical income limit, with weights given by each state's share of total health expenses, was 90.2 percent of the FPL. The categorical income limit in the model is set to match this 90.2 percent weighted average limit. Next, among the 34 states that had a Medicaid medically needy program in 2009, 30 states had a medically needy income limit below the FPL, and 23 states had a medically needy asset limit below $\$2,500$. The corresponding weighted average medically needy income and asset thresholds across the states with a medically needy program were 41.9 percent of the FPL and $\$1,950$, respectively. We set the medically needy income and asset thresholds to match these weighted average limits. A summary of the health insurance parameters is given in table 1.

3.4.3 Health transition and death probabilities

The health transition matrix must guarantee that, for each age and educational level, 60, 39.9, and 0.1 percent of consumers have low, high, and catastrophic medical expenses, respectively. Similarly, the survival probabilities must ensure that the age-specific survival probabilities are consistent with what we observe in the data. The following discussion explains how we adjust the health transition matrix to ensure consistency with the data. Using our MEPS sample, we first estimate age, health, and education specific health transition and survival probabilities by running an ordered probit regression of next period's health on current age, age squared, education, health, and interaction terms. Next, we scale the survival probabilities estimated from the MEPS to match the age-specific survival probabilities reported by the Social Security Administration. This last step is necessary since individuals drop out of the MEPS when they become institutionalized, which leads to upward biased survival probabilities. Lastly, we iterate on the transition matrix until the probabilities guarantee that, for each age and educational level, the correct percentage of consumers transition to each health state. That is, we iterate on the transition matrix, $Q_{j,e}(h, H)$, until $x^T Q_{j,e}(h, H) = x^T$, where $x^T = [0.6, 0.399, 0.001]$ denotes the probability distribution of consumers across health states. Note that this is an augmented version of the RAS-method, which is a method used to generate matrices that satisfy prespecified row and column sum constraints.

3.4.4 Preference, technology, and life cycle parameters

Consumers enter the model at age 20. We set j_r to 47 so that consumers start receiving Medicare and Social Security benefits at age 66. The maximum life span is set to 100 years. We follow Conesa and Krueger (1999) and set the population growth rate to 1.1 percent per year. Together with the estimated survival probabilities, these values give an old age dependency ratio (that is, the ratio of population older than 65 over population between 20 and 65) of 22.3 percent, slightly more than the 20.9 percent reported by the 2009 U.S. Census. Capital's share of income is set to 0.36. We follow CastaÒeda et al. (2003) and set the depreciation rate to 0.059. We set the consumption share in intratemporal utility to 0.574 to match estimates in French (2005), and set σ to 2.742 to match an intertemporal elasticity of substitution (IES) of 0.5. Next, consumers are endowed with one unit of time in every period that can be allocated to work and leisure. We set the grid for labor supply to $\ell \in \{0, 0.225, 0.300, 0.375\}$, which corresponds to working zero hours, part time, full time, and overtime, respectively. We let $\xi(h)$ be equal to 1 for agents with low and high health expenditures, and 0 for agents with catastrophic expenses. Given data from the MEPS, we estimate deterministic labor productivity profiles, ϵ_{je}, by regressing the logarithm of wages on age, education, higher-order moments of age, and interaction terms. Lastly, we set the fraction of consumers with at least a four-year college degree to 23.5 percent and let the remaining share be denoted as consumers without a college degree to match estimates in the MEPS. A summary of the non-insurance parameters that are determined outside the model is given in table 2.

The final set of parameters is determined jointly in equilibrium, a summary of which is given in table 3. We calibrate θ to generate a steady state GDP per capita of 1 in the benchmark economy. The discount factor is set to 0.927 to match a capital-to-output ratio of 3. The low value of the discount factor is attributed to consumers being subject to idiosyncratic shocks to both labor productivity and health expenditures. Consumers accordingly save more in our model than in standard life cycle models where consumers only face shocks to labor productivity. A lower value of β is thus needed to generate the desired capital-to-output ratio. The Social Security replacement rates are calibrated to match average Social Security benefits across individuals with and without a college degree. The assumption that benefits depend on education is motivated by the fact that Social Security benefits are tied to lifetime earnings in the United States, which is correlated with educational attainment. Next, we set the consumption floor, $\underline{c}$, to match the average annual Supplemental Nutrition Assistance Program benefits reported by the United States Department of Agriculture. Lastly, we calibrate the mass of 20-year-olds that qualify for employer-provided insurance to match the mass of individuals with either private or employer insurance in the data.

3.4.5 Earnings process

We follow CastaÒeda et al. (2003) and calibrate the parameters of the labor earnings process to match the empirical earnings distribution in the United States. We choose a right-skewed productivity shock process to match the top decile of the earnings distribution, and calibrate the variance of the process to match the dispersion observed in the data. The comparison of the labor earnings distribution in the model and the data reported in table 4 shows that the model successfully matches the empirical distribution. A similar comparison of the wealth distribution is given in table 5. Although we do not calibrate the model to match this distribution, the table verifies that the model generates a concentration and right skewness of wealth that is comparable to what we observe in the data.

3.5 Results

We use the model to run two policy experiments. We start by studying the macroeconomic effects of eliminating Medicare from the benchmark economy. We then analyze an alternative reform where we eliminate both Medicare and Medicaid.

Before we present the policy experiments, we first evaluate the performance of the model by comparing the distribution of medical expenses by age and provider in the model and the data. Figure 3 shows that the benchmark model captures several features of the age-specific insurance distribution in the MEPS. The model is consistent with the fact that medical expenses in young age are largely paid out-of-pocket, by Medicaid, and by private and employer-provided insurance plans, and that the majority of expenses in old age are covered by Medicare. Quantitatively, the model also largely matches the percentage of expenses covered by Medicare, private, and employer-provided insurance plans over the life cycle. The model underestimates the expenses paid out-of-pocket and overestimates the expenses covered by Medicaid. The latter discrepancy between the model and the data is partly driven by the Medicaid income tests. Recall that we set the categorical and medically needy income thresholds to match the 90.2 and 41.9 percent weighted average limits in the data, respectively. The corresponding median categorical and medically needy income thresholds are 64.0 and 50.5 percent. Using the median rather than weighted mean income limits in the model lowers the percentage of expenses covered by Medicaid for the young and increases the corresponding share for the old. We choose the weighted mean estimates to better match the insurance distribution of the elderly. A sensitivity analysis reported in section 6 shows that our results are robust to using median income and asset tests. With easier access to Medicaid, however, a larger share of the elderly is able to substitute into Medicaid. As a result, the saving to the government from eliminating Medicare is only 44 cents on the dollar in the model with median income and asset limits, in contrast to 46 cents on the dollar with weighted average limits. Lastly, figure 3 shows that other insurance programs cover about 7 percent of health expenses of all age groups in the data. In the model, this insurance plan corresponds to our combined food stamps and basic medical relief program. We find that the share of health expenses paid by this program declines with age and approaches zero for the elderly, a result that follows directly from the assumption that consumers have to forfeit all assets and work zero hours to qualify for the program.

3.5.1 Eliminating Medicare

Our first policy experiment involves an unexpected elimination of Medicare. Starting from the benchmark economy, we lower the insurance coverage rate of Medicare to zero and study the macroeconomic effects as the economy transitions to a new steady state without Medicare. By "macroeconomic effects," we mean the effects of the policy reform on consumption, assets, output, insurance choice, government spending, and welfare. We study not only comparative statics but also the full transition path between the economies, which Conesa and Krueger (1999) and Krueger and Ludwig (2016) have shown to be crucial for evaluating Social Security and education policy reforms.

Macroeconomic aggregates, insurance enrollment, and government spending

Table 6 compares the steady state of the economy with and without Medicare. Eliminating Medicare leads to a 2.7 percentage point reduction in payroll taxes and a 1.3 percent increase in wages. The increase in wages follows from the 4.4 percent increase in capital per capita. Capital increases as consumers raise their saving to finance the higher cost of medical expenses in old age. The combination of higher wages and lower payroll taxes raises labor supply and generates an increase in output per capita of 2.0 percent.

Table 7 reports the insurance distributions in the two steady states. As consumers are allowed to combine health insurance policies (for instance, an old consumer on Medicare can purchase private insurance), we define a consumer's main insurance provider as the insurance plan that pays for the largest share of her medical expenses. For instance, a consumer is defined to be on employer-provided health insurance if most of her medical expenses are paid by the employer. The table also reports the percentage of total medical expenses covered by each insurance plan. Note that total health expenses are equal in the two economies since all medical spending is non-discretionary in the model. In the benchmark economy, 18.2 percent of consumers have Medicare as their primary health insurance provider. Not surprisingly, eliminating Medicare increases the percentage of self-insured consumers and the fraction of consumers with private insurance as their main provider. More interestingly, we find that the policy reform raises the percentage of consumers with Medicaid as their primary health insurance provider from 16.4 to 20.8 percent. As Medicaid coverage increases, total medical expenses covered by Medicaid also rises from 22.1 to 32.3 percent.

Figure 4, which plots Medicaid enrollment by age in the economy with and without Medicare, shows that all of the increase in the Medicaid coverage rate is driven by the elderly, who respond to the removal of Medicare by partially substituting Medicaid for Medicare. To better understand how Medicare affects Medicaid enrollment, we compute the percentage of people in each age bracket that qualify for Medicaid under the categorical and medically needy criterion in the two economies. Recall that consumers qualify for Medicaid under the categorical criterion if the sum of their gross income and interest earnings is below the categorical threshold. Similarly, consumers qualify for Medicaid under the medically needy criterion if the sum of their gross income and interest earnings net of out-of-pocket medical expenses and their assets are both below the corresponding limits. Given our calibration of the categorical income limit and Social Security replacement rates, none of the elderly qualify for Medicaid under the categorical criterion in the two economies. All of the increase in the Medicaid coverage rate is thus driven by an increase in the percentage of elderly that qualifies under the medically needy criterion because the reform lowers the elderly's net income. Note that net income declines even though the elderly respond to the reform by increasing their labor supply, saving, and purchase of private health insurance.

Medicare spending accounts for 3.3 percent of GDP in the benchmark economy, about \$489 billion. How much the government saves by eliminating the program depends on what happens to spending on other social insurance programs such as Medicaid, food stamps, and Social Security. Table 8 decomposes fiscal spending on these programs in the economy with and without Medicare. Eliminating Medicare leads to a rise in Medicaid expenses from \$545 to \$796 billion as the share of old consumers that qualify for the program increases. It also raises the fraction of elderly that goes on food stamps, but total spending on the program remains constant at \$94 billion since fewer young consumers go on food stamps in the economy without Medicare. Lastly, government spending on Social Security benefits increases from \$699 to \$714 billion as wages surge following the rise in capital. These estimates show that government spending on other social insurance programs increases by

$266 billion following the reform. As a result, we find that the elimination of Medicare leads to a $223 billion annual reduction in fiscal spending. Accordingly, although Medicare spending accounts for 3.3 percent of GDP in the benchmark economy, the reform only results in a 1.5 percentage point reduction in government spending in the long run.

The $223 billion annual reduction in fiscal spending following the $489 billion cut in Medicare spending shows that the government saves only 46 cents for every dollar it cuts on Medicare expenses. Our results also show that most of the loss in saving following the reform can be attributed to spending on Medicaid. Put together, these findings suggest that for every dollar the government cuts on Medicare, spending on Medicaid increases by 51 cents. Consequently, eliminating Medicare will have only limited long-run fiscal effects if the current Medicaid eligibility criteria are maintained.

Recall that total health expenses are equal in the two economies and that the $489 billion cut in Medicare expenses leads to an increase in Medicaid spending by $251. The remaining $238 billion increase in health spending can be attributed to private insurance, self-insurance, employer insurance, and food stamps. We find that the elderly partially respond to the reform by purchasing private health insurance, which in turn increases spending by private insurance from $296 to $388 billion. Similarly, the increase in the percentage of self-insured consumers leads to a surge in out-of-pocket medical spending from $565 to $706. Lastly, spending by employer insurance increases from $472 to $476 billion, and spending by food stamps increases from $100 to $101 billion. Note that total health expenses covered by food stamps exceed total government spending on food stamps since consumers have to forfeit all assets to qualify for the program.

We next examine the transition path between the economy with and without Medicare. We choose a transition duration of 100 years to ensure that the economy has sufficient time to transition to the new steady state. Starting from an initial steady state with Medicare, figure 5 shows how capital, output, consumption, and effective labor supply evolve during the first 50 years following the elimination of the program. Although the comparative statics exercise in table 6 showed that consumption per capita is 1.8 percent higher in the steady state without Medicare, the transition path shows that consumption initially drops by about 0.7 percent. In fact, the percentage change in consumption compared to the initial steady state remains negative for several years following the elimination of Medicare. Consumption declines during the transition as consumers accumulate assets to finance the higher cost of medical expenses in old age. As we have shown earlier, the surge in capital leads to higher wages and labor supply, both of which enable the consumers to save and consume more in the long run.

Welfare

This section quantifies the ex-ante and ex-post welfare effects of the reform. While the ex-ante measure refers to the effect on an unborn consumer under the veil of ignorance, the ex-post measure refers to the effect on the current cohorts.

Ex-ante welfare We quantify the ex-ante welfare effect by means of consumption equivalent variation. That is, we measure how much a consumer's consumption must increase in all periods and contingencies in the economy with Medicare to make her indifferent between the economy with and without Medicare. Let $V^M(s)$ denote the value of a consumer of type s in the steady state with Medicare. Similarly, let $V_t^N(s)$ denote the value of a consumer of type s that enters the economy in period t of the transition. Finally, let $\Phi_0(s) = \Phi(1, e, h, \eta, 0, i)$ denote the mass of newborns of type s. Given our functional form for utility, we obtain the following expression for the ex-ante welfare effect on an unborn consumer under the veil of ignorance that enters the economy in period t of the transition:

$$CEV_t^{Tr} = \left[\frac{\int V_t^N(s)\, \Phi_0(ds)}{\int V^M(s)\, \Phi_0(ds)} \right]^{\frac{1}{\gamma(1-\sigma)}}. \tag{3.17}$$

Figure 6 shows how ex-ante welfare evolves during the first 50 years of the transition. That is, it shows how much consumption must increase in all periods and contingencies in the economy with Medicare to make an unborn consumer under the veil of ignorance that enters the economy in period t of the transition indifferent between the benchmark economy and the transition. We find that ex-ante welfare increases by 2.1 percent for a consumer that enters in the first period of the reform. This welfare gain further increases over the transition. Consequently, we find that ex-ante welfare increases by 3.6 percent in the long run. Ex-ante welfare is higher without Medicare because payroll taxes are lower and wages are higher in the economy without Medicare, both of which facilitate higher consumption and saving.

Ex-post welfare For unborn cohorts, we do not need to compare utility across different consumers. Once a consumer is born, however, she begins as either college educated or non-college educated, and either has or does not have employer-provided health insurance. As life progresses, the consumer experiences a sequence of shocks to her health status and labor productivity. Furthermore, at any point in time there are consumers of different ages. Consequently, if we want to calculate some sort of aggregate ex-post welfare measure of the impact of eliminating Medicare, we have to compare gains and losses across very different consumers.

We use three alternative measures to quantify the ex-post welfare effect on the current cohorts. None of them are perfect, and we discuss the advantages and disadvantages of each measure. Our first measure avoids the problem of comparing gains and losses across different consumers by simply computing the mass of people that benefit from the reform. This measure tells us whether or not the reform would win on a vote among all consumers aged 20 and older in the period that the reform is implemented.

For our second measure, we compute the dollar value of how much wealth must change in the initial steady state to make the consumer weakly better off in the economy with Medicare than in the transition. Given that consumers are not allowed to borrow, there exists a lower bound for this change in wealth. For instance, consider a consumer that is better off in the economy with Medicare. Since wealth must be non-negative, there might not exist a sufficiently large reduction in wealth that would make this consumer indifferent between the economy with and without Medicare. For each type s, we therefore compute the minimum change in wealth, $WEV^1(s)$, that satisfies the following constraints:

$$\begin{aligned} \min \quad & WEV^1(s) \\ s.t. \quad & V^M\left(j,e,h,\eta,a+WEV^1(s),i\right) \geq V_1^N(j,e,h,\eta,a,i) \\ & a+B+WEV^1(s) \geq 0. \end{aligned} \tag{3.18}$$

We then compute the average welfare effect of the reform by integrating across consumers:

$$WEV^1 = \int WEV^1(s)\,\Phi(ds)\,. \tag{3.19}$$

Finally, for our third measure, we follow Chatterjee et al. (2007) and quantify the ex-post welfare effects by computing the average consumption equivalent variation across consumers. To do this, we first compute the percentage change in consumption in all periods and contingencies that is needed to make a consumer of type s indifferent between the two economies:

$$CEV(s) = \left[\frac{V_1^N(s)}{V^M(s)}\right]^{\frac{1}{\gamma(1-\sigma)}}, \tag{3.20}$$

where $V^M(s)$ and $V_1^N(s)$ denote the value of a consumer of type s in the steady state with Medicare and in the first period of the transition, respectively. We then compute the average welfare effect of the reform by integrating across consumers:

$$\overline{CEV} = \int CEV(s)\,\Phi(ds)\,. \tag{3.21}$$

Unlike the second measure, this measure does not control for consumers' different levels of initial consumption, different assets, or different length of their remaining lifetime.

We start by examining how support for the policy varies with age. This is illustrated in figure 7, which plots the percentage of consumers in different age brackets that would vote in favor of eliminating Medicare. Our result shows that the majority of young consumers are better off without Medicare. In particular, we find that the percentage of votes by age in favor of eliminating the program exceeds 50 percent for all ages up to the age of 48. This result is due to the wage and tax effect discussed earlier. Although it takes time to transition to the new steady state, these consumers are still young enough to reap most of the benefits associated with higher labor earnings. The majority of older consumers, on the other hand, are better off with Medicare. Note, however, that the percentage of votes by age in favor of eliminating the program does not decline monotonically with age. We find that the percentage of consumers that are better off without Medicare increases late in life. This is driven by the interplay between Medicare and Medicaid highlighted earlier. That is, more old consumers qualify for Medicaid in the economy without Medicare, which in turn lowers their cost of going through the transition. After summing across votes, we find that 56.8 percent of the population alive in the period of the reform is better off without Medicare. That is, the majority of the population would vote in favor of eliminating the program.

Next, we turn to our second welfare measure, which quantifies the ex-post welfare effect by computing the dollar value of how much wealth must change in the initial steady state to make the consumer weakly better off in the economy with Medicare than in the transition. We then compute the average change in welfare across the population that would benefit and lose from the elimination of Medicare by summing across consumers in the two groups. Our estimate shows that the winners experience an average welfare gain that is equivalent to receiving $\$3,600$ higher wealth in the steady state with Medicare. In contrast, the losers experience an average welfare loss that is equivalent to at least a $\$27,700$ reduction in wealth. The average welfare gain across the 56.8 percent of the population that would benefit from the elimination of Medicare is thus considerably lower than the average welfare loss experienced by the remaining population. As a result, we find that the elimination of Medicare lowers aggregate welfare, and that the per capita welfare loss of the reform is equivalent to at least a $\$9,900$ reduction in wealth in the initial steady state. Recall that this measure binds for some consumers. That is, some consumers will be strictly better off in the economy with Medicare even if they forfeit all of their current wealth. In this case, we find that the constraint binds for 9.4 percent of the population.

Finally, in terms of consumption equivalent variation, we find that the winners experience an average welfare gain that is equivalent to receiving 1.9 percent higher consumption in all periods and contingencies in the initial steady state, and that the losers experience an average welfare loss of 7.0 percent. When we average the percentage gains and losses across all consumer types, we find that the average change in the different consumption equivalent variations is a decline of 2.0 percent.

Our discussion so far has shown that the majority of the population alive in the period of the reform is better off without Medicare. Yet, aggregate welfare is higher in the benchmark economy since the welfare gain experienced by those that benefit from the reform is outweighed by the welfare loss experienced by the rest of the population. The remaining part of this section studies how these heterogeneous welfare effects vary across consumers in different health and educational states, and across consumers with different wealth and labor earnings, a summary of which is given in table 9.

We find that the majority of college and non-college educated consumers are better off without Medicare, but that both groups experience a reduction in average welfare following the elimination of the program. Next, our results show that 56.3, 57.5, and 61.8 percent of consumers with low, high, and catastrophic medical expenses, respectively, are better off without Medicare. This follows from the fact that the majority of young consumers in all three health states benefit from the reform, which can be confirmed by examining the age- and health-specific voting outcomes reported in figure 8. Although the majority of consumers in all three health states benefit from the reform, their average welfare nevertheless declines. In particular, we find that consumers with low, high, and catastrophic medical expenses, respectively, experience an average welfare loss that is equivalent to receiving at least $\$10,300$, $\$9,400$, and $\$1,400$ lower wealth in the steady state with Medicare. The finding that welfare declines by less for consumers in catastrophic health, which also holds under our third welfare measure, is driven by the fact that most of these consumers are covered by food stamps or Medicaid. As shown in table 10, 72.1 percent of consumers with catastrophic medical expenses are enrolled in food stamps or Medicaid in the steady state with Medicare. This lowers the insurance value provided by Medicare to these consumers, which in turn lowers their welfare loss from the reform.

Lastly, we examine how welfare varies with wealth and labor earnings. Whereas the majority of consumers in the first four wealth quintiles are better off without Medicare, only 14.2 percent of consumers in the top wealth quintile benefit from the reform. This is largely driven by the observation that consumers at the top of the wealth distribution are older on average than consumers at the bottom of the wealth distribution. Moreover, the latter group is more likely to qualify for Medicaid, which in turn lowers their cost of eliminating Medicare. Finally, we find that about 70 percent of consumers in the second, third, and fourth labor earnings quintile benefit from the reform. In contrast, the majority of consumers in the first and fifth quintile of the earnings distribution are better off with Medicare.

3.5.2 Eliminating Medicare and Medicaid

The preceding subsection identified an important relation between Medicare and Medicaid. In particular, we found that the percentage of old consumers that qualified for Medicaid was higher in the economy without Medicare. A large share of the elderly therefore responded to the policy reform by substituting Medicaid for Medicare, which in turn lowered their cost of going through the transition. The substitutability between Medicare and Medicaid also implied that the elimination of Medicare would have limited long-run fiscal implications if the current Medicaid eligibility criteria were maintained. Given these findings, we therefore end this section with a brief analysis of the macroeconomic effects of eliminating both Medicare and Medicaid. Starting from the benchmark economy, we lower the Medicare and Medicaid insurance coverage rates to zero and study the effects as the economy transitions to its new steady state.

Eliminating both programs leads to a 37.8 percent surge in capital per capita as consumers accumulate assets to finance the higher cost of medical expenses throughout their life. This almost ninefold increase in capital compared to what we found when we only eliminated Medicare highlights Medicaid's significant insurance role in the economy. The combination of 11.0 percent higher wages and 10.0 percentage points lower payroll taxes raises labor supply and generates an increase in output per capita of 14.5 percent.

Table 7 showed that eliminating Medicare increases the percentage of expenses paid by private insurance plans from 12.0 to 15.7 percent. Eliminating Medicaid further increases this fraction to 43.2 percent. This shows that public insurance crowds out private insurance in the economy by discouraging consumers from purchasing insurance. Similar results are reported by Cutler and Gruber (1996), who estimate the extent of private insurance crowd-out following the 1987-1992 expansion of Medicaid eligibility to pregnant women and children.

Our estimates show that public spending declines by $777 billion on impact when we eliminate Medicare and Medicaid, about 75 percent of the $1.03 trillion the government spends on these programs in the benchmark economy. As the economy approaches the new steady state, we find that the reform leads to an $832 billion annual reduction in fiscal spending. This additional long-run reduction in public expenditures can be attributed to spending on food stamps, which increases during the first years of the transition but eventually declines following the surge in saving, the last of which raises the relative cost of going on food stamps in the model.

Next, we examine the ex-ante welfare effect of the reform, and find that ex-ante welfare is higher in the economy without Medicare and Medicaid. In particular, we find that consumption has to increase by 7.8 percent in all periods and contingencies in the steady state with Medicare and Medicaid to make an unborn consumer under the veil of ignorance indifferent between the two steady states. That said, this measure fails to account for the costs of transiting between the steady states. It also abstracts from the reform's heterogeneous welfare effects on consumers of different types. After accounting for these costs, we find that eliminating Medicare and Medicaid lowers aggregate welfare, and that the per capita welfare loss of the reform is equivalent to at least a $\$29,500$ reduction in wealth in the initial steady state. As noted earlier, this measure binds for some consumers. That is, some consumers will be strictly better off in the initial steady state with Medicare and Medicaid even if they forfeit all of their current wealth. We find that the constraint binds for 37.4 percent of the population. Finally, we find that 19.4 percent of the population alive in the period of the reform is better off without both Medicare and Medicaid. That is, the majority of the population would not vote in favor of eliminating both programs. While our previous result showed that young consumers would benefit from the elimination of Medicare, we find that the majority of all age groups would be worse off if both programs were to be removed.

3.6 Sensitivity analysis

We have conducted a wide range of sensitivity analyses, and we find that our main results are robust. That is, the findings that aggregate ex-post welfare declines if we eliminate Medicare, that old consumers partially substitute Medicaid for Medicare, and that part of the reduction in government spending from eliminating Medicare is offset by higher spending on other social insurance programs are robust to alternative parameterizations of the model. We limit our discussion here to two robustness checks. First, we consider an alternative parameterization of the model where we lower the Medicare copayment parameter. Then we examine the implications of using median rather than weighted mean Medicaid income and asset limits. In both cases we recalibrate the model to match the same targets as in section 4. A comparison of the macroeconomic effects of eliminating Medicare under different parameterizations of the model is given in table 11.

Lower Medicare copayment parameter The copayment parameter for Medicare was set to match the age-specific insurance distribution in the data. Here we consider an alternative parameterization of the model where we set the Medicare copayment parameter to match the average share of expenses paid by Medicare across individuals with Medicare as their primary insurance provider. Given data from the MEPS, we obtain a Medicare copayment parameter of 29.1 percent.

Lowering the Medicare copayment parameter from 50.0 to 29.1 percent increases the percentage of medical expenses paid by Medicare from 19.8 to 28.1 percent. This increase can be attributed to a reduction in the percentage of expenses paid out-of-pocket, by Medicaid, and by private insurance. Higher Medicare expenses translate into higher payroll taxes in the initial steady state of this economy. As a result, we find that eliminating Medicare leads to a 4.0 percentage points reduction in payroll taxes in this economy, compared to the 2.7 percentage points reduction in payroll taxes reported in section 5.1.

We find that our result regarding how much the government will save by eliminating the program is robust to this alternative parameterization of the model. Whereas the government saves 46 cents for every dollar it cuts on Medicare in the benchmark model, it saves 49 cents for every dollar it cuts on Medicare in this model. Our finding that 56.4 and 56.8 percent of the population alive in the period of the reform would benefit from the elimination of Medicare in this model and in the benchmark model, respectively, also shows that the welfare implications of eliminating Medicare are comparable in the two models. That said, using a lower Medicare copayment parameter further increases the elderly's cost of going through the transition. As a result, we find that the per capita welfare loss of the reform is equivalent to at least a $\$14,700$ reduction in wealth in the initial steady state under this parameterization of the model, compared to at least a $\$9,900$ reduction under the benchmark parameterization.

Median Medicaid income and asset limits We end this section by studying the effects of eliminating Medicare in a model with median rather than weighted mean Medicaid income limits. That is, we set the categorical income limit to match the 64.0 percent median categorical income limit across states, and set the medically needy income and asset thresholds to match the 50.5 percent and $\$2,000$ median medically needy income and asset limit across the states with a medically needy program.

Using median rather than weighted mean Medicaid eligibility limits increases the percentage of elderly that qualifies for Medicaid in the model, which in turn lowers their cost of going through the transition. As a result, we find that the aggregate welfare loss from eliminating Medicare is higher in the benchmark model than in the model with median Medicaid eligibility limits. In particular, we find that the per capita welfare loss of the reform is equivalent to at least a $\$9,500$ reduction in wealth in the initial steady state under this parameterization of the model, slightly less than the $\$9,900$ reduction reported in section 5.1. Next, we find that the majority of the population alive in the period of the reform would benefit from the elimination of Medicare under both parameterizations of the model. While 56.8 percent of the population would vote for the policy reform in the benchmark model, we find that 56.6 percent of the population would benefit from the elimination of Medicare in the model with median Medicaid eligibility thresholds. Lastly, our results show that the fiscal implications of the policy reform are similar in the two models. Recall from section 5.1 that the government saves 46 cents for every dollar it cuts on Medicare expenses. In comparison, we find that the government saves 44 cents for every dollar it cuts on Medicare in the model with median Medicaid eligibility limits.

3.7 Conclusion

This paper has developed an overlapping generations model to study the role of Medicare in the macroeconomy. We used the model to quantify the effects of an unexpected elimination of Medicare on macroeconomic aggregates, insurance enrollment, government spending, and welfare. We found that a large share of the elderly responded to the reform by substituting Medicaid for Medicare, which in turn increased spending on Medicaid from 3.6 to 5.3 percent of GDP. Spending on Social Security benefits also increased from 4.7 to 4.8 percent of GDP due to a rise in wages following an increase in capital. As a result, we found that the government saved only 46 cents for every dollar it cut on Medicare.

We then examined the welfare effects of the reform, and found that ex-ante welfare was higher in the steady state without Medicare. In particular, we found that consumption had to increase by 3.6 percent in all periods and contingencies in the steady state with Medicare to make an unborn consumer under the veil of ignorance indifferent between the two economies.

Lastly, we have examined the ex-post welfare effects of the reform on the current cohorts. Our estimates showed that the majority of young consumers would benefit from the policy change due to the reform's effect on wages and payroll taxes. The majority of the elderly, on the other hand, were better off in the economy with Medicare. After summing across all age brackets, we found that 56.8 percent of the population alive in the period of the reform would benefit from the elimination of Medicare. Finally, we showed that the average welfare gain across the winners of the reform was considerably lower than the average welfare loss experienced by the remaining population. As a result, we found that the elimination of Medicare lowered aggregate welfare, and that the per capita welfare loss of the reform was equivalent to at least a $\$9,900$ reduction in wealth in the initial steady state.

We have also studied an alternative policy reform where we eliminated both Medicare and Medicaid. The elimination of both programs led to a surge in capital and labor supply, which in turn increased output per capita by 14.5 percent. It also resulted in a 31.2 percentage points increase in private insurance coverage and a 10.0 percentage points reduction in payroll taxes. Lastly, we found that the reform lowered aggregate ex-post welfare, and that only 19.4 percent of the population alive in the period of the reform was better off in the economy without Medicare and Medicaid.

This paper has abstracted from two channels that are likely to influence our results. First, we did not account for demographic changes in the model. In particular, we did not account for the projected increase in the old age dependency ratio, which will raise the future fiscal burden of Medicare. Second, the health-expenditure-to-GDP ratio has risen steadily since the 1960s and is projected to continue to increase in the future. To overcome the future fiscal pressure from Medicare and Medicaid, the government will have to raise taxes, lower the public insurance coverage rates, or change the eligibility rules, an example of which would be to increase the age at which individuals can claim Medicare. We leave it to future work to address how our results regarding the macroeconomic effects of Medicare are affected by these channels.

We also leave it to future research to examine two additional extensions of our paper: optimal fiscal policy and a small open economy framework. The optimal fiscal policy approach can be used to identify ways to finance the transition from an economy with Medicare to an economy without Medicare where the new equilibrium is constrained Pareto optimal. Conesa and Garriga (2008) use this approach to study Social Security reforms and find that cohort-specific labor income taxes can be used to shift the welfare gains between present and future generations. Lastly, we considered a closed economy where accumulation of assets leads to an increase in the wage rate, which increases the welfare for an unborn consumer under the veil of ignorance. Future research should examine how our results would change if we instead considered a small open economy framework where the increase in accumulation of assets may not increase the wage rate.

Table I: Insurance parameters determined outside the model

Parameter	Description	Source	Value
χ_P	Private insurance copayment parameter	MEPS	0.229
χ_E	Employer insurance copayment parameter	MEPS	0.229
χ_{CARE}	Medicare copayment parameter	MEPS	0.500
χ_{CAID}	Medicaid copayment parameter	MEPS	0.138
y^{cat}	Categorical income limit	Kaiser Family Foundation	0.197
y^{mn}	Medically needy income limit	Kaiser Family Foundation	0.092
a^{mn}	Medically needy asset limit	Kaiser Family Foundation	0.041

Table II: Non-insurance parameters determined outside the model

Parameter	Description	Source	Value
J	Maximum life span (100 years)		81
j_r	Age for SS and Medicare (66 years)		47
	Population growth rate	Conesa and Krueger (1999)	0.011
α	Capital income share		0.360
δ	Depreciation rate	CastaÒeda et al. (2003)	0.059
γ	Consumption share in utility	French (2005)	0.574
σ	IES $= 0.5$		2.742
ℓ_p			0.225
ℓ_f	Indivisible labor		0.300
ℓ_e			0.375
$\xi(h)$	Health-specific labor productivity		1,1,0
	Fraction of consumers with college degree	MEPS	0.235

Table III: Parameters determined jointly in equilibrium

Parameter	Description	Target	Value
θ	Total factor productivity	GDP pc $= 1$	0.647
β	Discount factor	Capital/output $= 3$	0.927
b_c	SS replacement rate	Average SS benefits college $\approx \$14,200$	0.374
b_{nc}	SS replacement rate	Average SS benefits non-college $\approx \$11,900$	0.313
$\underline{c}$	Consumption floor	Average food stamps $\approx \$1,300$	0.028
	Employer insurance	Share with private or employer $= 0.508$	0.464
	Scale for health care costs	Health expenditure/output $= 0.165$	1.803
σ_η	Variance	Labor earnings Gini $= 0.630$	4.051
η_{top}	Productivity at the top	Labor earnings top 1% $= 0.148$	24.657
π_{top}	Probability at the top	Labor earnings top 10% $= 0.435$	0.004
ρ_n	Persistence	2-year persistence: Bottom 80% $= 0.940$	0.901
ρ_{top}	Persistence at the top	2-year persistence: Top 1% $= 0.580$	0.775

Table IV: Labor earnings distribution (percent)

	Quintiles					Top			
	1st	2nd	3rd	4th	5th	90-95	95-99	99-100	Gini
Data	-0.40	3.19	12.49	23.33	61.39	12.38	16.37	14.76	0.63
Benchmark	0.26	4.79	9.79	20.59	64.56	11.83	16.77	14.78	0.63
w/o Medicare	0.42	5.20	9.82	20.44	64.13	11.75	16.65	14.67	0.62

Table V: Wealth distribution (percent)

	Quintiles					Top			
	1st	2nd	3rd	4th	5th	90-95	95-99	99-100	Gini
Data	-0.39	1.74	5.72	13.43	79.49	12.62	23.95	29.55	0.78
Benchmark	0.22	0.48	4.93	18.27	76.10	15.98	25.79	15.15	0.75
w/o Medicare	0.22	0.46	4.43	17.80	77.09	16.33	26.26	15.24	0.75

Table VI: Comparative statics: Economy with and without Medicare

Variable		Without Medicare (percentage change from benchmark)
y	Output pc	2.0
k	Capital pc	4.4
h	Avg hours	2.1
c	Consumption pc	1.8
N	Effective labor pc	0.7
w	Wage rate	1.3
		(percentage point change from benchmark)
τ	Tax rate	-2.7
r	Interest rate	-0.3

Table VII: Insurance distribution and medical expenses

	Head count by main provider (percent of population)		Medical expense (percent of total medical expenses)	
	Benchmark	Without Medicare	Benchmark	Without Medicare
Private	8.6	15.1	12.0	15.7
Employer	33.0	33.3	19.2	19.3
Self	18.8	26.1	22.9	28.6
Medicare	18.2	0.0	19.8	0.0
Medicaid	16.4	20.8	22.1	32.3
FS+MR	5.0	4.7	4.0	4.1

Table VIII: Fiscal implications

	Spending (percent of GDP)	
	Benchmark	Without Medicare
Medicare	3.3	0.0
Medicaid	3.6	5.3
Social Security	4.7	4.8
FS+MR	0.6	0.6

Table IX: Ex-post welfare effects

Variable	Votes in favor (%)	WEV^1 (dollars)	$\overline{CEV}$ (percent)
Entire population	56.8	$-9,900$	-2.0
Winners and losers			
Winners	100.0	$3,600$	1.8
Losers	0.0	$-27,700$	-7.0
Education			
Non-college	56.2	$-9,300$	-2.0
College	58.6	$-12,100$	-1.8
Medical expenses			
Low	56.3	$-10,300$	-2.0
High	57.5	$-9,400$	-2.0
Catastrophic	61.8	$-1,400$	-1.2
Wealth (quintile)			
1st	70.6	$1,000$	-1.6
2nd	77.6	$2,800$	0.2
3rd	71.8	$-1,800$	-0.3
4th	51.9	$-10,700$	-2.7
5th	14.2	$-39,600$	-5.2
Labor earnings (quintile)			
1st	40.1	$-16,600$	-5.6
2nd	69.5	$-4,500$	-0.8
3rd	70.2	-900	0.1
4th	68.8	$-6,000$	-0.5
5th	36.0	$-21,400$	-2.8

Table X: Medicaid and food stamps enrollment by health in steady state with Medicare (percent of population)

Health	Medicaid	Food stamps
Low	12.6	4.9
High	37.4	5.1
Catastrophic	28.0	44.1

Table XI: Comparative statics: Effect of eliminating Medicare under different parameterizations of the model

	Variable	Benchmark	Lower Medicare copay	Median Medicaid limits
y	Output pc	2.0	3.1	1.8
k	Capital pc	4.4	7.1	4.0
h	Avg hours	2.1	3.2	1.7
c	Consumption pc	1.8	2.6	1.5
N	Effective labor pc	0.7	1.0	0.6
w	Wage rate	1.3	2.1	1.2
τ	Tax rate	-2.7	-4.0	-2.5
r	Interest rate	-0.3	-0.4	-0.3

Figure 3.1: Medical expenses by age and health state (MEPS)

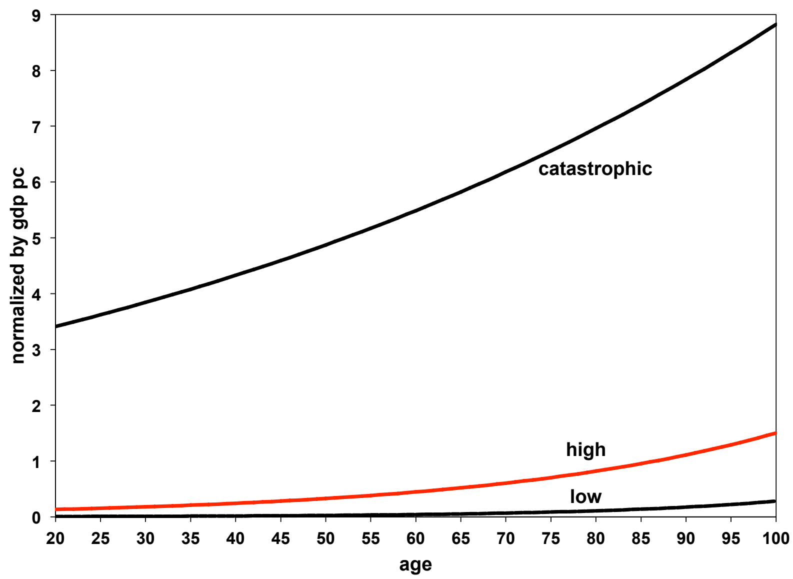


Figure 3.2: Medical expense risk by age (MEPS)

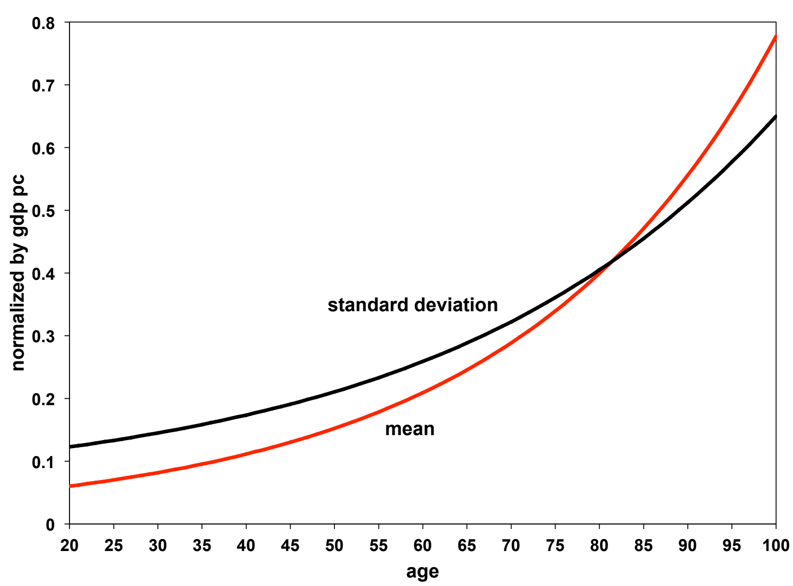


Figure 3.3: Distribution of medical expenses by age and provider

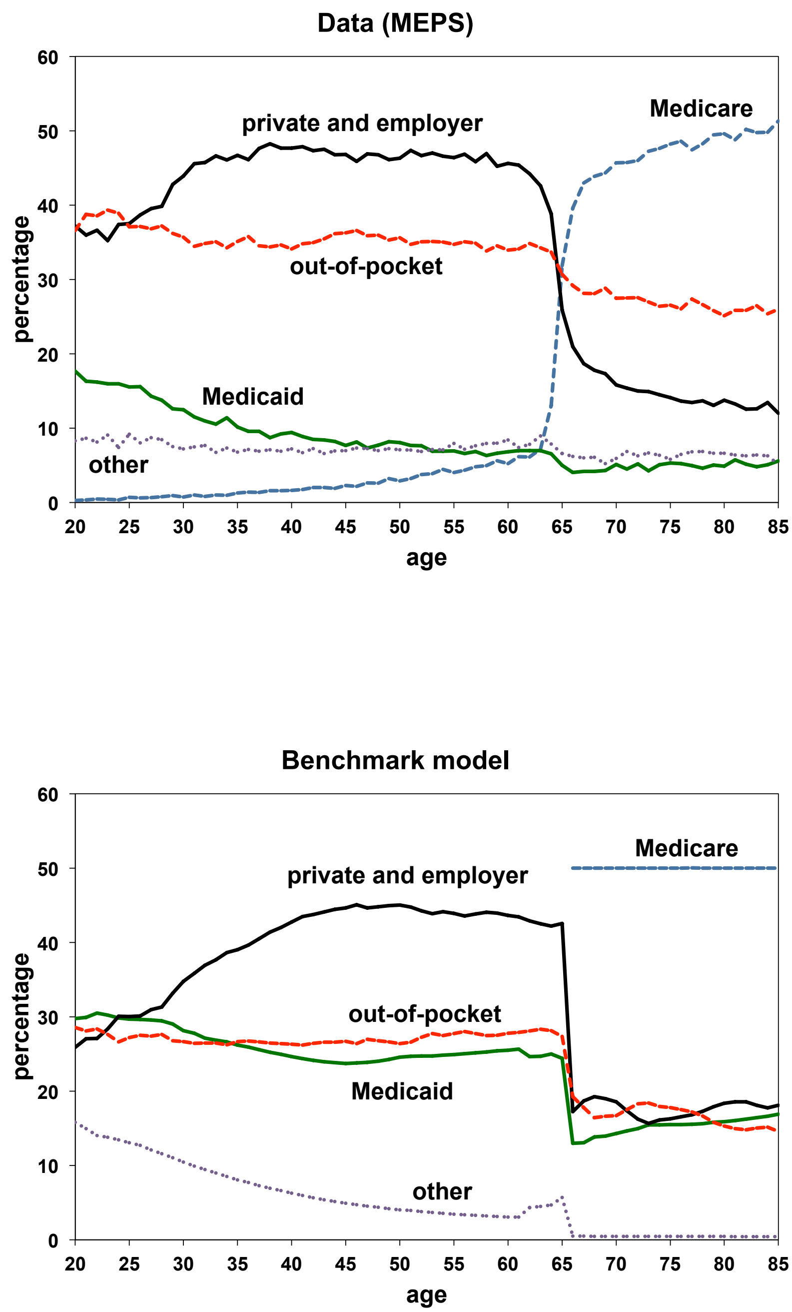


Figure 3.4: Medicaid enrollment by age

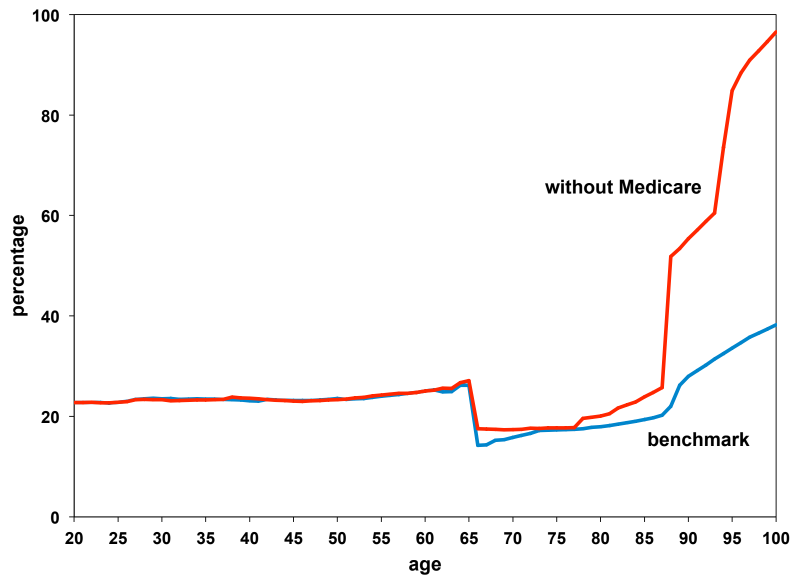


Figure 3.5: Transition from economy with Medicare to economy without: Aggregates

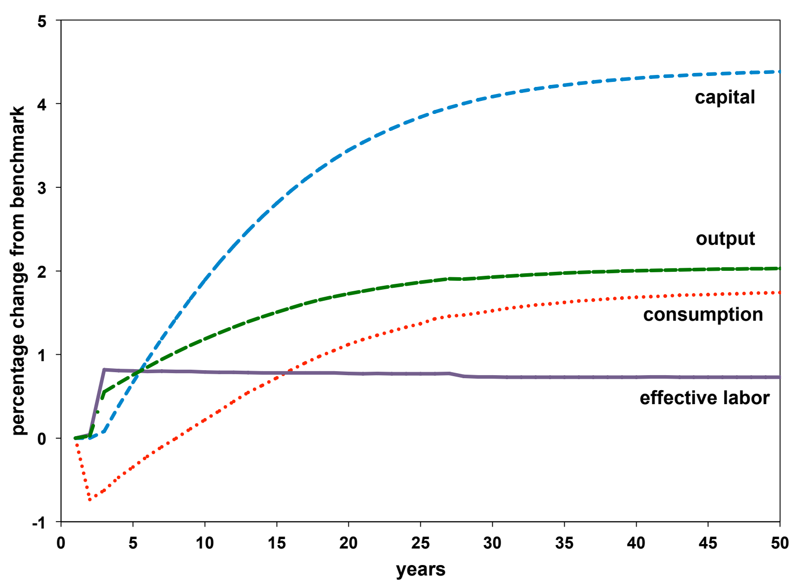


Figure 3.6: Transition from economy with Medicare to economy without: Ex-ante welfare on unborn consumer

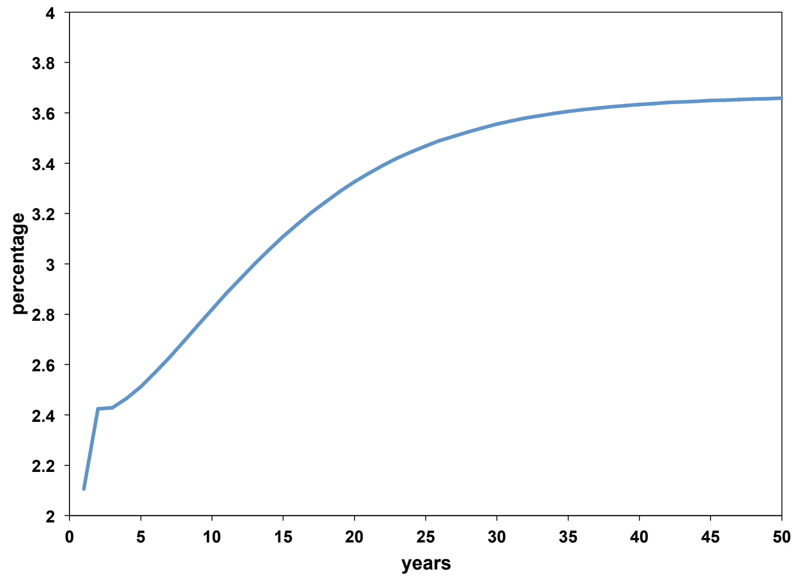


Figure 3.7: Percentage of votes in favor of reform by age

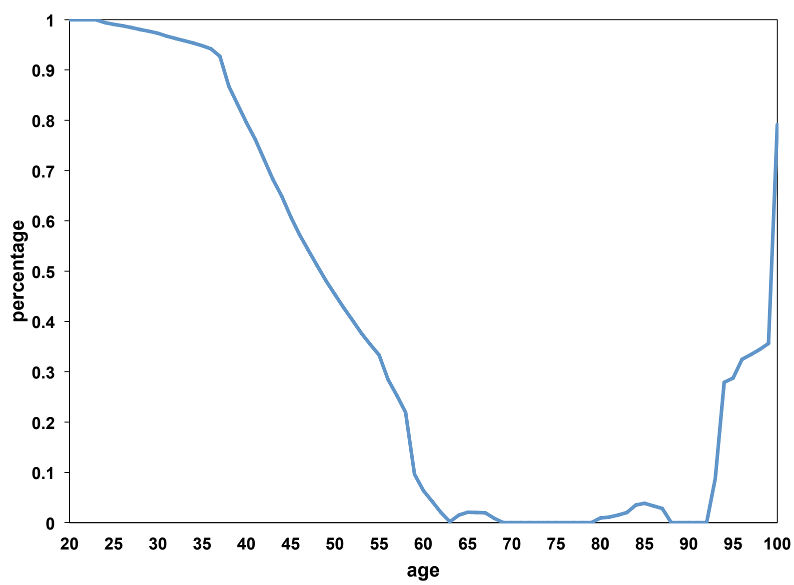
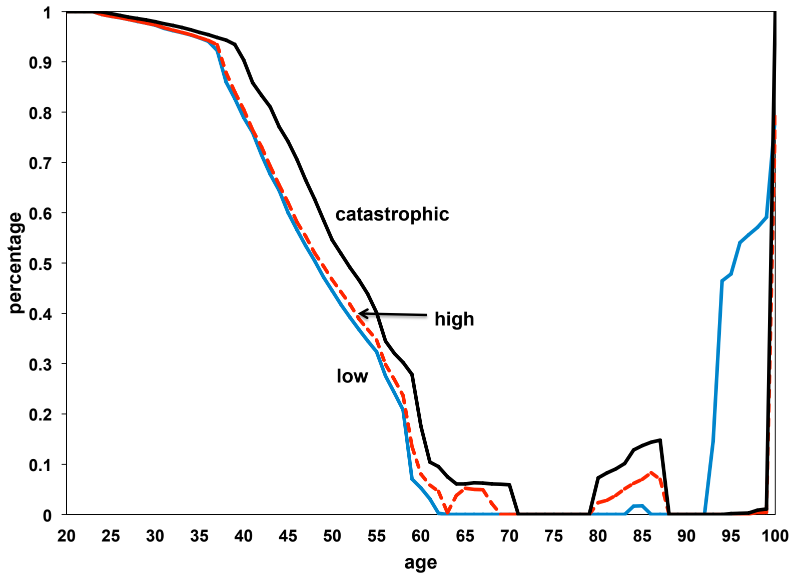


Figure 3.8: Percentage of votes in favor of reform by age and health



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Appendix A

Appendix to Chapter 1

Table A.1: Primary commodities SITC Rev.2 classification

Code	Commodity description
00	Live animals chiefly for food
01	Meat and meat preparations
02	Dairy products and birds' eggs
03	Fish, crustaceans, mollucs, preparations thereof
041	Wheat and meslin, unmilled
042	Rice
043	Barley, unmilled
044	Maize (corn), unmilled
045	Cereals, unmilled (no wheat, rice, barley or maize)
05	Vegetables and fruit
06	Sugar, sugar preparations and honey
0711	Coffee green, roasted; coffee substitutes containing coffee
0721	Cocoa beans, whole or broken, raw or roasted
074	Tea and mate
075	Spices
121	Tobacco unmanufactured; tobacco refuse
08	Feeding stuff for animals, not included unmilled cereals
21	Hides, skins and furskins, raw
22	Oil seeds and oleaginous fruit
232	Natural rubber latex; nat. rubber and sim. nat. gums
244	Cork, natural, raw and waste (including in blocks/sheets)

Table A.1: (continued)

Code	Commodity description
245	Fuel wood (excluding wood waste) and wood charcoal
246	Pulpwood (including chips and wood waste)
247	Other wood in the rough or roughly squared
261	Silk
263	Cotton
264	Jute, other textile bast fibres, n.e.s., raw, processed but not spun
265	Vegetable textile fibres and waste of such fibres
268	Wool and other animal hair (excluding wool tops)
27	Crude fertilizers and crude materials (excluding coal)
281	Iron ore and concentrates
286	Ores and concentrates of uranium and thorium
287	Ores and concentrates of base metals, n.e.s.
288	Non-ferrous base metal waste and scrap, n.e.s.
289	Ores and concentrates of precious metals, waste, scrap
28901	Ores and concentrates of precious metals
29	Crude animal and vegetable materials, n.e.s.
32	Coal, coke and briquettes
333	Crude petroleum and oils obtained from bituminous minerals
34131	Liquefied propane and butane
41	Animal oils and fats
42	Fixed vegetable oils and fats

Table A.2: Analyzed countries with quarterly data

Code	Country	Period	Source GDP	Source ToT
ARG	Argentina	1993q1 – 2015q2	IFS/IMF	IFS/IMF
AUS	Australia	1990q1 – 2016q2	IFS/IMF	IFS/IMF
AUT	Austria	1990q1 – 2016q2	OECD	OECD
BEL	Belgium	1993q1 – 2016q2	IFS/IMF	IFS/IMF
BRA	Brazil	1996q1 – 2016q2	OECD	OECD
CAN	Canada	1990q1 – 2016q2	IFS/IMF	IFS/IMF
CHE	Switzerland	1990q1 – 2016q2	OECD	IFS/IMF
CHL	Chile	1996q1 – 2016q2	OECD	OECD

Table A.2: (continued)

Code	Country	Period	Source GDP	Source ToT
COL	Colombia	2000q1 – 2016q2	OECD	OECD
CRI	Costa Rica	1991q1 – 2016q1	OECD	OECD
CZE	Czech Republic	1996q1 – 2016q2	OECD	OECD
DEU	Germany	1990q1 – 2016q2	OECD	IFS/IMF
DNK	Denmark	1990q1 – 2016q2	OECD	IFS/IMF
ESP	Spain	1990q1 – 2016q2	OECD	IFS/IMF
EST	Estonia	1995q1 – 2015q2	OECD	OECD
FIN	Finland	1990q1 – 2016q2	OECD	OECD
FRA	France	1990q1 – 2016q2	OECD	OECD
GBR	United Kingdom	1990q1 – 2016q2	OECD	OECD
GRC	Greece	1990q1 – 2016q2	OECD	IFS/IMF
HKG	Hong Kong	1990q1 – 2016q2	IFS/IMF	IFS/IMF
HUN	Hungary	1995q1 – 2016q2	OECD	OECD
IDN	Indonesia	1990q1 – 2016q2	OECD	OECD
IND	India	1996q2 – 2015q4	OECD	IFS/IMF
IRL	Ireland	1990q1 – 2014q4	OECD	IFS/IMF
ISL	Iceland	1997q1 – 2016q2	OECD	OECD
ISR	Israel	1990q1 – 2016q2	IFS/IMF	IFS/IMF
ITA	Italy	1990q1 – 2016q2	OECD	IFS/IMF
JPN	Japan	1990q1 – 2016q1	IFS/IMF	IFS/IMF
KOR	South Korea	1990q1 – 2012q4	IFS/IMF	IFS/IMF
LTU	Lithuania	1995q1 – 2016q2	OECD	OECD
LUX	Luxembourg	1995q1 – 2016q1	OECD	OECD
LVA	Latvia	1995q1 – 2016q2	OECD	OECD
MAR	Morocco	1990q1 – 2013q3	IFS/IMF	IFS/IMF
MEX	Mexico	1993q1 – 2016q2	OECD	OECD
NLD	Netherlands	1990q1 – 2016q2	OECD	OECD
NOR	Norway	1990q1 – 2016q2	OECD	OECD
NZL	New Zealand	1990q1 – 2016q2	OECD	OECD
PHL	Philippines	1996q1 – 2006q4	IFS/IMF	IFS/IMF
POL	Poland	1995q1 – 2016q2	OECD	OECD
PRT	Portugal	1995q1 – 2016q2	OECD	OECD
SGP	Singapore	1990q1 – 2015q2	IFS/IMF	IFS/IMF

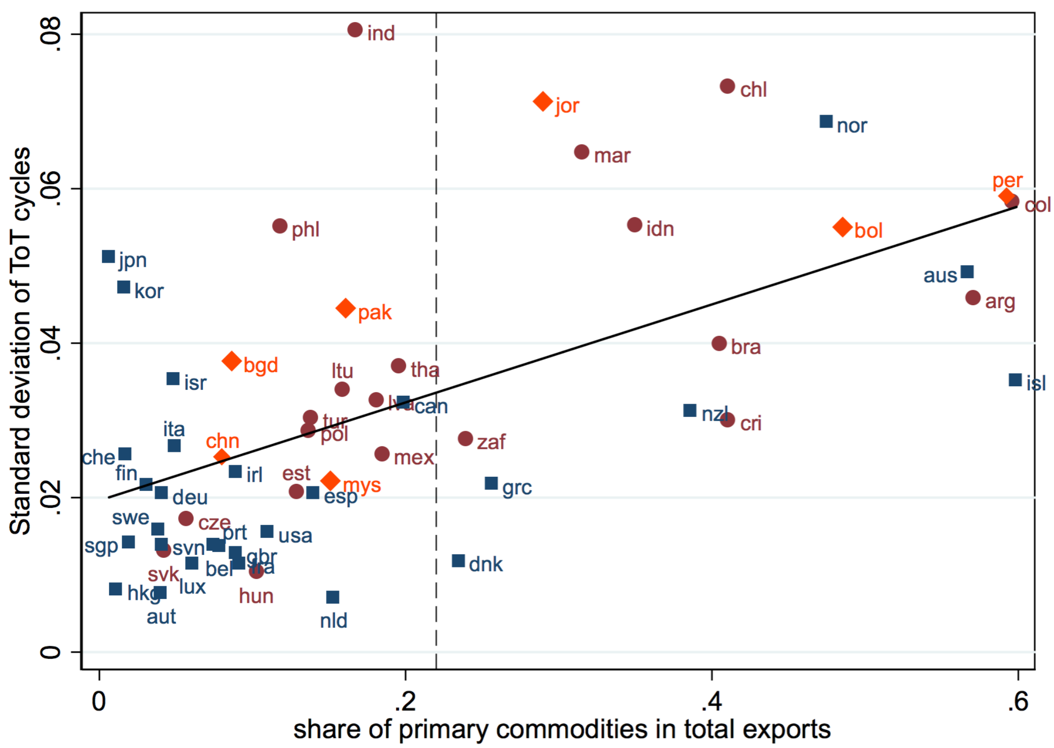
Table A.2: (continued)

Code	Country	Period	Source GDP	Source ToT
SVK	Slovakia	1997q1 – 2016q2	OECD	OECD
SVN	Slovenia	1995q1 – 2016q2	OECD	OECD
SWE	Sweden	1990q1 – 2015q2	OECD	IFS/IMF
THA	Thailand	1993q1 – 2015q2	IFS/IMF	IFS/IMF
TUR	Turkey	1991q1 – 2015q2	OECD	IFS/IMF
USA	United States	1990q1 – 2015q2	OECD	OECD
ZAF	South Africa	1990q1 – 2015q2	OECD	OECD

Table A.3: Analyzed countries with annual data

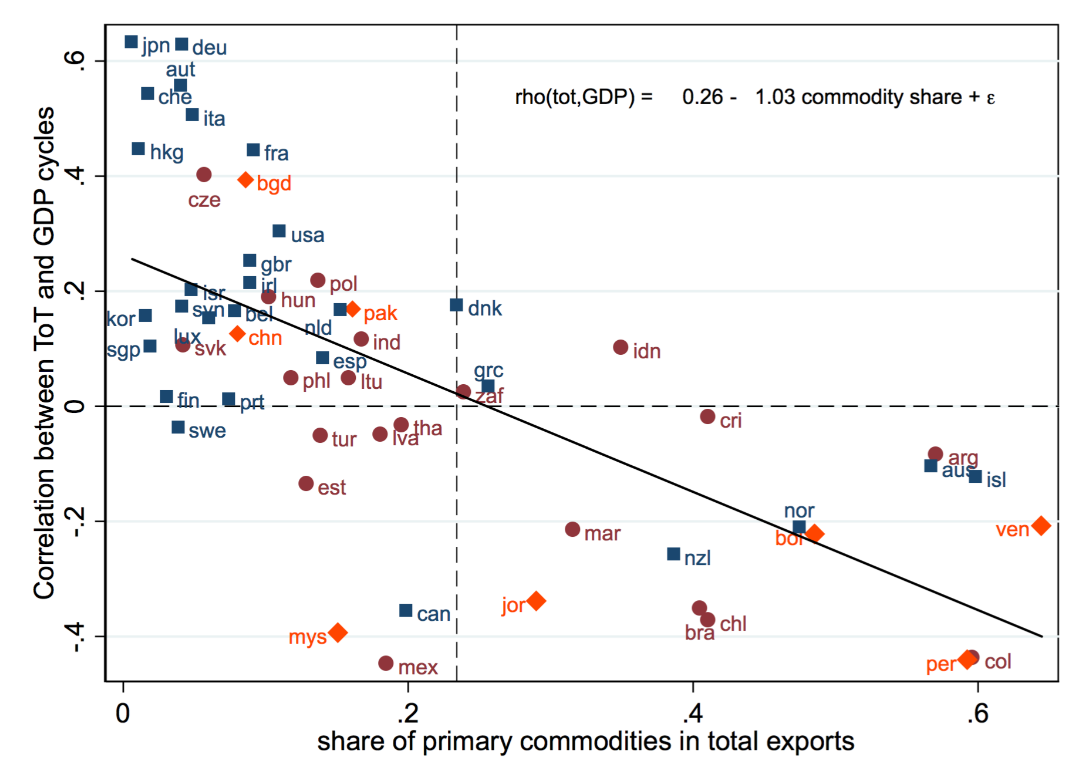
Code	Country	Period	Source GDP	Source ToT
BGD	Bangladesh	1990 – 2014	IFS/IMF	WDI
BOL	Bolivia	1990 – 2014	IFS/IMF	WDI
CHN	China	1990 – 2015	IFS/IMF	WDI
JOR	Jordan	1990 – 2011	IFS/IMF	IFS/IMF
MYS	Malaysia	1990 – 2014	IFS/IMF	WDI
PAK	Pakistan	1990 – 2015	IFS/IMF	IFS/IMF
PER	Peru	1990 – 2014	IFS/IMF	WDI
VEN	Venezuela	1990 – 2013	IFS/IMF	WDI

Figure A.1: Standard deviation of terms of trade for PCX and non-PCX



Note: High-income countries (GNI per capita of US$12,616 or more, according to the World Bank criterion) are designated by a blue square, while low-income countries are red circles. Low-income countries for which only annual data are available are depicted by an orange diamond. The dashed vertical line is the threshold above which a country is a PCX.

Figure A.2: Correlation between terms of trade and real GDP



Note: High-income countries (GNI per capita of US$12, 616 or more, according to the World Bank criterion) are designated by a blue square, while low-income countries are red circles. Low-income countries for which only annual data are available are depicted by an orange diamond. The dashed vertical line is the threshold above which a country is a PCX.

Appendix B

Appendix to Chapter 2

Solving for the Equilibrium

System of equations that characterize equilibria in case 1:

$$\begin{aligned}
H_N^1 &= \frac{w_H^1 - Bp_z\left(H_N^1, H_M^2, H_N^2\right)}{\bar{\theta}_1} \\
H_N^2 &= \frac{w_H^2 - Bp_z\left(H_N^1, H_M^2, H_N^2\right)}{\bar{\theta}_2}(1-\gamma) \\
H_M^2 &= \frac{w_H^1 - Bp_z\left(H_N^1, H_M^2, H_N^2\right)}{\bar{\theta}_2}\gamma \\
p_z\left(H_N^1, H_M^2, H_N^2\right) &= \frac{1-\lambda}{\lambda}\frac{A\left(H_N^1 + H_M^2\right)\left(H_N^1 + H_M^2\right) + A\left(H_N^2\right)\left(H_N^2\right)}{B\left(2 - H_N^1 - H_M^2 - H_N^2\right)}
\end{aligned}$$

which can be reduced to:

$$\begin{aligned}
\bar{\theta}_1 H_N^1 &= A\left[\left(1+\frac{\bar{\theta}_1}{\bar{\theta}_2}\gamma\right)H_N^1\right] - \frac{1-\lambda}{\lambda}\frac{\left[\left(1+\frac{\bar{\theta}_1}{\bar{\theta}_2}\gamma\right)H_N^1\right]w_H^1 + H_N^2 w_H^2}{\left(2-\left(1+\frac{\bar{\theta}_1}{\bar{\theta}_2}\gamma\right)H_N^1 - H_N^2\right)} \\
\frac{\bar{\theta}_2}{1-\gamma}H_N^2 &= A\left(H_N^2\right) - \frac{1-\lambda}{\lambda}\frac{\left[\left(1+\frac{\bar{\theta}_1}{\bar{\theta}_2}\gamma\right)H_N^1\right]w_H^1 + H_N^2 w_H^2}{\left(2-\left(1+\frac{\bar{\theta}_1}{\bar{\theta}_2}\gamma\right)H_N^1 - H_N^2\right)}
\end{aligned}$$

System of two equations that characterize equilibria in case 2:

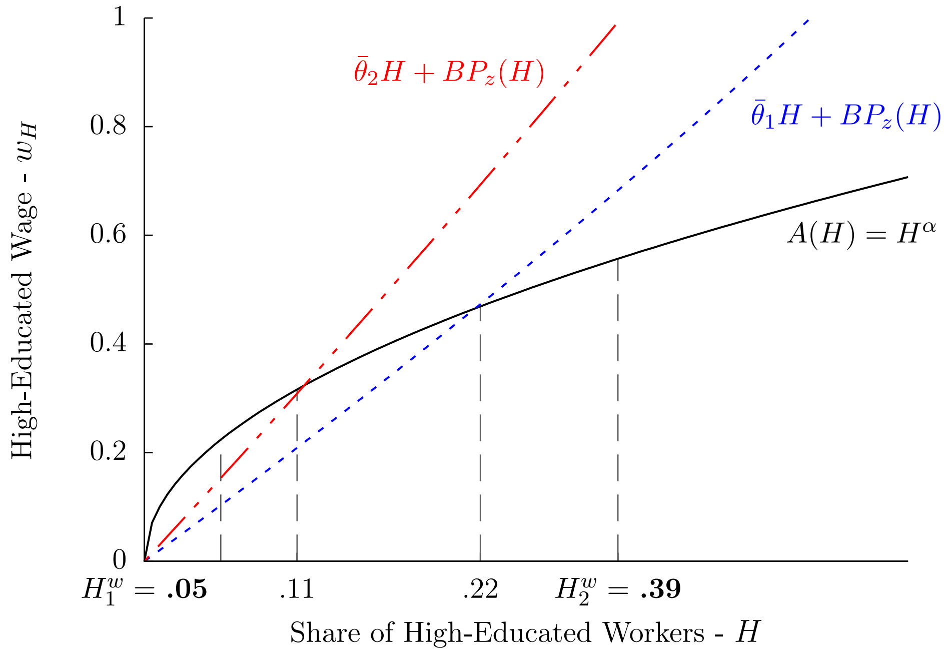
$$
\begin{aligned}
H_N^1 &= \frac{w_H^1 - Bp_z\left(H_N^1, H_M^1, H_N^2\right)}{\bar{\theta}_1}\left(1-\gamma\right) \\
H_N^2 &= \frac{w_H^2 - Bp_z\left(H_N^1, H_M^1, H_N^2\right)}{\bar{\theta}_2} \\
H_M^1 &= \frac{w_H^1 - Bp_z\left(H_N^1, H_M^1, H_N^2\right)}{\bar{\theta}_1}\gamma \\
p_z\left(H_N^1, H_M^1, H_N^2\right) &= \frac{1-\lambda}{\lambda}\frac{\left[A\left(H_N^1\right)\left(H_N^1\right) + A\left(H_N^2 + H_M^1\right)\left(H_N^2 + H_M^1\right)\right]}{B\left(2 - H_N^1 - H_M^1 - H_N^2\right)}
\end{aligned}
$$

We solved these systems using a Quasi-Newton fixed point algorithm. However, we found a solution only for a range of parameter values. This is a general feature of increasing returns to scale models that generate agglomeration and present multiplicity of equilibria. When the stock of workers of each type is exogenous, finding the set of parameter values for which there is one, multiple or no equilibria is easier. However, in the model of this paper the education choice makes the stock of HE workers endogenous which complicates the task. Further characterizing the equilibria is a priority in our research agenda.

Additional Graphs

Case 2

Figure A.1: Specialization Patterns: Case 2



Additional Tables

To provide a glimpse of changes in the European job and migration structure, columns 1 to 4 of Table A.1 show the employment shares of occupations, by migration status. Columns 5 to 8 show their percentage point changes between 1996 and 2010. We consider three migration categories: native-born ($Native$), born in a EU-15 country different to the one of current residency ($EU15$), and born outside the EU-15 bot working in one of our selected countries ($nonEU15$). We pool employment for each group and occupation across our 15 European countries.

Table A.1: Summary Statistics Occupations

	ISCO	Employment Share (2010)				$N_{2010} - N_{1996}$			
	code	Pop	Native	FB-EU15	FB-Rest	Pop	Native	FB-EU15	FB-Rest
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
High-Paying Occupations		38.16	39.74	41.64	23.50	17.58	21.82	46.47	-22.05
Corporate managers	12	4.80	4.98	6.74	2.73	8.79	12.79	36.73	-35.88
Physical, mathematical, and engineering professionals	21	4.14	4.29	4.84	2.61	51.04	59.24	52.93	-20.21
Life science and health professionals	22	2.41	2.46	2.58	1.97	9.08	12.54	52.60	-35.46
Other professionals	24	5.08	5.27	6.94	2.99	40.97	47.52	107.77	-18.27
Managers of small enterprises	13	4.70	4.73	5.71	4.20	-16.10	-16.42	16.19	-17.15
Physical and engineering associate professionals	31	4.41	4.65	4.37	2.38	15.70	20.74	13.68	-22.00
Other associate professionals	34	9.47	10.03	7.93	5.11	28.55	33.09	65.91	-1.17
Life science and health associate professionals	32	3.14	3.34	2.51	1.51	16.30	22.94	43.25	-42.30
Medium-Paying Occupations		33.81	34.20	31.19	31.20	-20.64	-20.05	-27.93	-21.24
Stationary and plant related operators	81	1.14	1.18	1.01	0.80	-19.64	-15.20	-51.45	-51.20
Metal, machinery and related trades workers	72	4.56	4.70	3.44	3.64	-26.08	-24.29	-47.88	-28.01
Drivers and mobile plant operators	83	4.59	4.60	3.20	4.88	-8.66	-9.03	-38.50	-0.18
Office clerks	41	9.71	10.30	7.64	5.19	-21.83	-18.79	-11.15	-42.21
Precision, handicraft, craft printing printing and related trade workers	73	0.38	0.38	0.44	0.36	-55.50	-56.22	-22.14	-48.90
Extraction and building trades workers	71	6.23	5.77	9.50	9.35	-10.77	-15.47	-25.21	17.12
Customer sevice clerks	42	2.42	2.50	2.25	1.82	-2.49	-1.14	58.57	-6.55
Machine operators and assemblers	82	2.99	2.99	2.47	3.12	-30.62	-29.01	-46.88	-46.14
Other craft and related trades workers	74	1.79	1.78	1.24	2.03	-39.12	-40.69	-14.95	-21.89
Low-Paying Occupations		28.03	26.06	27.17	45.30	12.37	5.92	-3.97	49.79
Laborers in mining, construction, manufacturing and transport	93	2.82	2.52	1.75	5.68	-12.84	-20.89	-35.69	39.61
Personal and protective service workers	51	11.45	11.09	10.50	14.81	18.11	14.10	15.60	56.72
Models, salespersons, and demonstrators	52	5.49	5.62	4.19	4.72	6.53	6.16	27.25	30.83
Sales and services elementary occupations	91	8.27	6.83	10.73	20.09	20.56	6.65	-18.70	53.16

Note: Occupations are ordered by their mean wage across 10 European countries across all years, following wage information in Goos, Manning and Salomons (2014). Columns 1 to 4 contain employment shares by migrant status, pooled across countries. Columns 5 to 8 contain growth rates of employment shares from 1996-2010.

Table A.2: ISCO-88 Major Groups and Skill Level

	Major Group	ISCO Education Level
1	Legislators and Managers	4
2	Professionals	4
3	Technicians and Associate professionals	3
4	Clerks	2
5	Service and Sales	2
6	Skilled Agricultural and Fishery	2
7	Craft and Related	2
8	Plant and Machine Operators	2
9	Elementary Occupations	1